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PHILIP'S EXPERIMENTS
OR, PHYSICAL SCIENCE AT HOME

BY

JOHN TROWBRIDGE

> Socrates says, that "no man goeth about a more godly purpose than he that is mindful of the good bringing up both of his own and other men's children."
>
> ROGER ASCHAM'S SCHOOLMASTER

NEW YORK
D. APPLETON AND COMPANY
1898

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1898.

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PREFATORY NOTE.

MANY boys think that they can not acquire knowledge in any subject outside a school. It is the object of this book to show that a few moments devoted each day, at home, to simple investigations can result in habits of self-reliance in the acquirement of a modern language and in the study of the art of drawing. I endeavor also to show how to cultivate a taste for mathematics by studying practical problems in surveying and in sailing a boat.

Many distinguished men have told me that their interest in Nature and in science was first aroused in walks with an interesting companion. My own taste for science and for drawing was stimulated by my father in the manner described in this little treatise; and I have endeavored to show how much a parent can accomplish in the formation of a son's tastes without special knowledge and without the expenditure of much time or money.

PHILIP'S EXPERIMENTS; OR, PHYSICAL SCIENCE AT HOME.

I.

My Dear Richard:

You ask me what method I have adopted in giving my son Philip what you are pleased to call his ability to do things. Philip certainly can use his eyes and hands, and he knows the value of persistent effort and self-reliance. I can claim some credit for the remarkable success he has had in his profession; for I have cultivated in him these qualities of persistence and self reliance; but I have done little in the direction of systematic education, of which you desire a complete outline for the use of your son. My efforts were in the uncultivated field of individual, unsystematic education. Almost every one has some fad, and mine has been the development of good fellowship between myself and my son—good comradeship when he was a boy, and good fellowship when he grew to be a man.

We have always worked together, Philip and I. You well remember I was a stupid fellow at school, and in college I did not distinguish myself. My interest in intellectual things was never really aroused until, by almost an accident while I was studying for my profession, a special case in actual life interested me, and I suddenly discovered a dormant faculty which had slumbered through all the systematic lectures and the systematic drill of my school and college life. How often it happens that some person, by a hint, a half-hour's talk, will have a more educating effect than months of schooling! And how often it happens that a suddenly awakened interest in some historical personage will make us look up a historical period with keen interest, when months of lectures on the same period when we were in college left no abiding impression! If there is any science of teaching, the existence of which I doubt, one must have the science, and one can not get it as you get a mechanical drill, *en masse* or by lectures; one must get it by individual effort.

When I examine my educational experience I find that my progress in science dates from a suddenly awakened interest in the problem of sailing a boat across a narrow channel through which there was a strong tideway. Up to that time I had learned my Euclid by heart, and did not comprehend a word of it. I had listened to lectures on natural philosophy, and had brought away a confused picture of men standing on stools having their hair electrified, of brilliant colors on a screen; in short, a Christmas phantasmagoria. The problem of the boat, however, called into play my powers of thinking, and I began to study mathematics, and found it a very interesting subject. My experience is not an isolated one. You will find that most men can date their intellectual rise from some suddenly awakened interest, which serves as the starting point for a mental inflammation. The most we can do in education is to form habits of study and point out the way. Our lectures and recitations can not impart real learning; this must be obtained by the man himself. We are solitary in our hours of real acquirement. Mental strength comes from wrestling in the closet with one subject for a long period of time. It is dissipated by the consideration of a great variety of subjects.

You may ask, Why did you select physics in order to train your boy's power of observation? Would it not have been better to take some subject in natural history? Can a boy make any advance in natural philosophy without considerable knowledge of mathematics? In reply to your questions I present the following considerations which I think are important, although I acknowledge that I was influenced by a natural leaning toward mechanics. Now as to these considerations. The illustrations of the working of natural forces lie about us on every side, and are involved in stretching the arms, in breathing, in riding the bicycle, in swimming, and in sailing a boat. Every boy is more or less interested in machines; he likes to see the wheels go round. There is a natural interest in moving bodies, in electricity, and in light. The reasoning faculty can be appealed to as well as the faculty of observation, and a material use can be made of the results of observation, which, conceal it and reprobate it as we may, is a powerful spirit of action and interest in boys as well as men.

I have noticed, too, that what Sir Isaac Newton calls "a competent faculty of thinking" can be trained by the study of physical problems. Our greatest thinkers have had strong leaning toward physics. Locke, the philosopher, associated with the physicists of his age, and when he was driven to the Continent, from fear of Charles II, sought the company of the natural philosophers in France and Holland. Count Rumford doubtless owed, in great measure, his success to his balance of judgment and insight in problems of natural philosophy; and the mental acumen shown by Benjamin Franklin came largely, I believe, from his habit of observing and weighing the physical causes of phenomena. While the subject of mathematics strengthens the mind in certain directions, the subject of physics broadens as well as strengthens, for the complete consideration of the simplest problem in mechanics, such as the length of run of an express train after the steam is shut off, requires a tonic exercise of the thinking powers, which will be found to be of use in the consideration even of problems in political economy.

You will find, in these notes of my experience in teaching Philip, descriptions of very simple experiments, such as he could perform with the means that every householder has, for such experiments often stimulate interest more than those performed by means of a complicated piece of apparatus. Lord Brougham thus speaks of the demonstrations of Professor Black, the propounder of the theory of latent heat:

"His experiments were often, like Franklin's, performed with the simplest apparatus; indeed, with nothing that could be called apparatus at all. I forget whether he showed us the experiment of a bladder filled with inflammable air and rising to the ceiling, which he had often shown to his friends in private, and which was the origin of the air balloon; but I remember him

of my business I have had to select a large number of boys for various subordinate positions in our firm, and I have found that country-bred boys are apt to have certain valuable qualities which are often lacking in city-bred boys. The latter sometimes have a smartness which has been obtained from too close contact with promiscuous crowds of men. There are, of course, high-minded city boys, but as a rule I find that I have to discharge more city boys than country boys. It certainly seems a sweeter thing for a boy to be in contact with Nature—with broad fields, with animals—rather than with congregations of humanity in crowded streets and hot places of amusement.

Accordingly, I have always lived in the country, within an hour's ride of the city. My place is somewhat extensive, consisting of mowing, pasture, and wood land. The original house was an old one, having been built shortly after General Washington laid down the cares of state and retired to Mount Vernon. Its style of architecture was the old colonial, not unlike the Craigie House at Cambridge. A spacious hall ran through the house, and a stately staircase ascended to the second floor by easy stages. The wall paper in this hall had various designs. On one panel there was a representation of the taking of Troy—the wooden horse and the armed men descending from its interior at night in the slumbering city. On another panel were scenes from the wanderings of Æneas. There was Queen Dido receiving the hero, and various enigmatical situations, the representation of which tempted one to stop on the stairway and endeavour to puzzle out the meaning. The walls of Philip's sleeping room were also covered with pictorial paper. There was the building of the Pyramids, and Alexander extending graciously his protection to the family of Darius. In a very prominent position one saw Bucephalus. I have particularly mentioned the pictorial wall paper, for I believe that the constant contemplation of it in the dawning hours of intelligence had a certain educating effect upon Phillip. He thinks himself that the pictures on the walls developed a certain capacity for drawing, for his eyes wandered over the designs, and he was always wondering why Alexander should have been represented apparently as speaking to him rather than to the wife of Darius, who was kneeling in an attitude which even an athlete could not long maintain. There was Alexander portrayed in a noble act; and the boy felt that lofty and noble actions are always to be emulated. One can never tell what lasting impressions may be made at a very early age. I am tempted to be dogmatic, and to recommend that your boy's room should be painted with scenes representing the great acts of noble men.

While these letters to you, Richard, will endeavour to prove to you my firm conviction that the influence of a father can be initially more powerful in shaping the character and forming the tastes of a boy than any other individual influence, I do not wish to underrate the influence of a mother. Philip says that the earliest remembrance of his infancy is that of a gentle, Madonna-like face bending over his cradle one spring evening while the robins sang in the orchard. Philip's mother has never been willing to delegate her offices to a nurse, except at rare intervals. I have sometimes been jealous of her complete absorption in her child, but I soon grew to estimate the value of this extraordinary attention which I felt inclined at first to believe could have been relegated to a servant.

My wife said that she was willing to leave to men the public rostrum and suffrage, if she could have the formation of the character of the coming man. She believes in the power behind the throne, and both Philip and I cheerfully acknowledge that we feel it and bow to it. Perhaps at this point in my confession I should state that Philip never went to a kindergarten, and therefore I can not answer your question in regard to the value of this method. I have a firm belief, somewhat puritanical perhaps, that boys should not expect to be amused, but should be taught to amuse. Professor Scribain says that the boys of the present generation have been brought up to believe that they should be entertained, and that he loses their attention at his lectures the moment that he calls upon their minds for an independent intellectual struggle. Many of them, he remarks, would like to have their subjects sent up to them in bed and served with their coffee. He claims that we are now receiving the fruits of the kindergarten method. I imagine that this is a hasty generalization, for the professor is somewhat old-fashioned, and can not to this day enjoy himself in an easy-chair. You should hear his tone of scorn when he speaks of "lolling boys." Philip's mother early enjoined upon him the duty of amusing me on my return from the city, and I really believe that by inculcating this self-denying principle in the boy she laid the principal foundation stone in that edifice which you are kind to praise.

But I fear I have digressed from the real subject of this letter, which is the effect of the pictorial environment of the boy's infancy. Philip tells me that when he awoke in the morning his eyes wandered over the wall papers, and he reflected upon the actions that he saw there portrayed. Often, too, he imagined other figures in the empty spaces, and he sought to better the grouping and the costumes. The helmet of Alexander troubled him greatly; it did not seem proper that the hero should wear it before the wife of Darius, who was bending in suppliance before him, surrounded by her children and the ladies of her court. Philip accordingly drew on the wall paper a rough representation of his father's silk hat just at the point of Alexander's outstretched hand. His mother chid him for marring the paper, but the rude attempt at drawing roused an idea within me. I resolved to provide him with a less expensive paper to experiment on, and my attempts to direct his art education will be made the subject of my next letter. In closing this epistle I must quote some remarks of our old Professor Scribain. He still occupies a chair in the university, and comes to see me often. His remarks can not, as an old writer says, fail to be an ornament at this place.

"Your idea of the importance of early environment to a child," said he to me, "reminds me of the method of Montaigne's father. For," says Montaigne, "he, among other rules, had been advised to make me relish science and duty by an unforced will and of my own voluntary motion, and to educate my soul in all liberty and delights, without any severity or constraint; which he was an observer of to such a degree, even of superstition, that some being of opinion that it troubles and disturbs the brains of children suddenly to wake them in the morning, and to snatch violently and overhastily from sleep (wherein they are much more profoundly involved than we), he caused me to be waked by the sound of some musical instrument, and was never unprovided of a musician for that purpose."

II.

I could not draw the simplest object, and it seemed the height of egotism to presume to teach drawing to Philip. I was supported, however, in my method by a remark in Ruskin's Elements of Drawing, which I will quote: "For the recommendation to the pupil to copy faithfully, and without alteration, whatever natural object he chooses to study, is serviceable, among other reasons, just because it gets rid of systematic rules altogether, and teaches people to draw, as country lads learn to ride, without saddles or stirrups; my main object being, at first, not to get my pupils to hold their reins prettily, but to 'sit like a jackanapes, never off'" (page xiv, preface).

I determined to require a drawing of something from Philip every day. When I returned from the city, almost the first question I asked was, "Well, what have you drawn to-day?" and when he brought his sketch to me I criticised it with him, and suggested certain improvements.

Our progress was very slow, and at times discouraging. The schoolmaster said that he should put into the school term, some time in the future, a three months' course in drawing, and he advised me to delay Philip's art education until there was a set teacher and a systematic course of lessons. He held up again the *monstrum horrendum* of loose methods and the danger of getting bad habits in drawing, which would cling to the future man. I could not learn, in reading the lives of great painters, that they had ever limited their efforts in drawing to set periods in the year, or that they had followed any particular method save that of constant practice and incessant observation. It was the little every day that, like compound interest, produced in time the large capital.

Sometimes Philip brought a copy of an oak leaf; sometimes an ambitious attempt at a representation of the house; then a copy of an engraving. I took care that he should have plenty of woodcuts of all sorts of objects, and I threw in his way some manuals of the art of drawing. I recommended him to draw with pen and ink, to give certainty of touch, and to prevent the indecision which arises from the ability to rub out. Practice in pen-and-ink drawing may be called the military training applied to the hand and eye.

Well, on the whole we advanced. The pile of drawings grew apace, and Philip had immense satisfaction in seeing the number of sketches he made. This was one of the lessons I was extremely anxious to inculcate—the little every day amounting to the immense in time. During my endeavours I came across an interesting bit in the life of the celebrated engineer George Stephenson the younger. It seems that his father was in the habit of training his son to interpret to him mechanical drawings of machinery, so that he should form the habit of conceiving the solid objects from the plans and sections represented in the drawings. I found a new faculty of enjoyment within myself which had lain until I had arrived at middle age, entirely unsuspected. I had lived all my life on a flat surface, and had not been able to conceive of the roundness of things. As soon as I got the hint—in studying how to direct Philip—that one could represent an object in plan by looking directly down upon it as if long pins were struck through every part of it into a sheet of paper, and could represent it in elevation by sticking pins through the same points into a vertical sheet of paper, I had the satisfaction of talking to my architect in town in a way which brooked no contradiction. I saw that he was surprised at my evident command of what belonged to his profession, and I enjoyed his air of respect. Better than this increase to my vanity was the feeling of knowledge. I was not helpless before plans and estimates which every man of affairs is called upon sooner or later to consider. I was determined that Philip too should be masterful in this subject.

There is this also to be said for the training of the hand and eye in copying every sort of object: that one thus trained observes much more closely natural objects than those persons who have not strived to cultivate the faculty of drawing which lies dormant in everybody to a greater or less extent. On our Sunday walks Philip was incessantly pointing out the forms of leaves, the arrangement of branches, and the disposition of light and shade. Moreover, one can work off depression of spirits and harassing cares and overmuch use of the mind by exercising the fingers in drawing. It is said that one can forget one's cares and the troubles of the world more completely and effectually by the study of mathematics than by means of a cigar or by the use of opium. Certainly it is true that a "man's mind a kingdom is," and he who can make his boy realize this great truth gives him a greater legacy than if he left him ten thousand a year. I wish you would try, Richard, to develop within yourself the faculty of drawing, and also the drawing of mathematics, such as I shall have frequent occasion to refer to in these notes on education. I am sure you would discover a new source of enjoyment. Do not wait too long. I hear that the greatest Greek scholar in Europe, who had fought the introduction of scientific studies into the university, suddenly became intensely interested during his last illness in the subject of physiology. A new world was opened to him, and then he died.

You can readily believe that my method in education did not go along without considerable hitching. I pinned my faith to the efficacy of a daily task which was as much a part of the day as the breakfast. If we devoted as much time to intellectual effort every day as we do to putting on and taking off our shoes, how much we might accomplish in a year! It was astonishing how many engagements Philip had which made a half hour for drawing difficult to obtain. If society forms a league to spoil a pretty girl, as some cynics maintain, it certainly seems to make it extremely difficult for a father to indulge in educational fads. Philip was now a dancing man. He was getting to be a club man and an athlete even at the age of twelve. However, I was persistent and patient, and I adopted Gideon's motto, "Faint but pursuing," and light slowly dawned after a while.

One of my heresies in teaching drawing was an effort to make Philip originate instead of to servilely copy what was before him. I suggested that he should cut out of a print certain figures, stick them on a white piece of paper, and draw certain objects around and between them, giving them suitable pictorial environment.

I was explaining my theory of education to Professor Scribain one evening, for after some months of practice I had become a *doctrinaire* like most educators. I had been waxing eloquent on the subject of a parent's responsibility, and I had found in the proper exercise of it a cure for many of the evils of society. The professor agreed with me in the main. "You will find much of your philosophy of education in Montaigne," said he. "In a letter to Diana de Foix he says, speaking of the education of a son:

"'Let an honest curiosity be planted in him to inquire after everything, and whatever there is of singular and rare near the place where he shall reside let him go and see it: a fine house, a fountain, an eminent man, the place where a battle was anciently fought, the passage of Cæsar or Charlemagne.'

"'Quæ Tellus sit lenta gelu, quæ putris ab æstu,
Ventus in Italiam quis bene vela ferat.'

(What lands are frozen, what are parched, explore,
And what wind bears us to the Italian shore.)

"He agrees also with Roger Ascham, that the pursuit of knowledge should be made alluring, for he says, 'I condemn all violence in the education of a gentle soul that is designed for honour and liberty' (letter to Madame d'Estissac).

"You are perfectly right, too, in endeavouring to give your son individual instruction at home. Very little is accomplished by endeavouring to teach children at an early age *en masse.* Montaigne says, in the same letter to Madame Diana de Foix, which I have already quoted:

"'Such as, according to our common way of teaching, undertake with one and the same lesson, and the same measure of direction, to instruct several boys of so differing and unequal capacities, need not wonder if in a multitude of scholars there are not found above two or three who bring away any good account of their time and discipline.' Indeed, this sending of boys away from home to school is a serious question. Have you ever read what Locke the philosopher says on this head in his treatise on education?

"Speaking of the effect of early associates, and of the danger to children from bad servants, he says: ''Tis a hard matter to prevent this mischief. You will have good luck if you never have a clownish or vicious servant, and if from them your children never get any infection.

But yet as much must be done toward it as can be, and the children kept as much as may be* in the company of their parents, and those to whose care they are committed.

"'For you will be ready to say, What shall I do with my son? If I keep him always at home he will be in danger to be my young master, and if I send him abroad how is it possible to keep him from the contagion of rudeness and vice, which is everywhere so in fashion? In my house he will perhaps be more innocent, but more ignorant too of the world; wanting these changes of company, and being used constantly to the same faces, he will, when he comes abroad, be a sheepish or conceited creature.

"'I confess both sides have their inconveniences. Being abroad, 'tis true, will make him bolder and better able to bustle and shift among boys of his own age, and the emulation of schoolfellows often puts life and industry into young lads. . . . As for that boldness and spirit which lads get among their playfellows at school, it has ordinarily such a mixture of rudeness and ill-timed confidence that those misbecoming and disingenuous ways of shifting in the world must be unlearned, and all the tincture washed out again, to make way for better principles and such manners as make a truly worthy man. . . . Nor does any one find, or so much as suspect, that that retirement and bashfulness which their daughters are brought up in makes them less knowing or less able women. Conversation, when they come into the world, soon gives them a becoming assurance, and whatsoever, beyond that, there is of rough and boisterous may in men be very well spared too, for courage and steadiness, as I take it, lie not in roughness and ill-breeding.

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* How much the Romans thought of the education of their children—a business that properly belonged to the parents themselves—see in Suetonius, August, § 64; Plutarch, in Vita Catonis Censoris, Diodorus Siculus, l, ii, cap. iii.

" 'Virtue is harder to be got than a knowledge of the world, and if lost in a young man is seldom recovered.' " (Locke on Education, p. 46.)

I had, too, my moments of elation, especially after Philip had handed to me a really good drawing which showed a remarkable advance, and like many reformers I burned to instruct the world. I wrote to an evening paper, "that last infirmity of noble minds," a plea for more individual instruction by parents, and I called down a severe reply from a professor of pedagogy, who intimated that I was wasting my time in doing what he could teach me to do by his science of teaching. I had to unburden my mind to Professor Scribain.

"Is there such a thing as the science of teaching?" said I.

"Not unless you've got the science," he replied.

I saw that he did not believe much in one man not proficient in a subject teaching another how to teach that subject.

Philip's mother was overcome at times with fear for the moral future of her son, and hearing him thus quote Locke she commended her fears to the professor.

"It is not to be expected, madam," said he, "that he will never fall into temptation. No amount of example or preaching can avail against the subtlety of certain temptations. The torrents of spring can break down all barriers. A man must experience certain passions before he can say, 'I shall never yield.' The strength of your teaching resides in this: You will have formed an accusing conscience. Your precepts and honourable examples and pure thoughts will constitute an angel choir which will sing to the prostrate man and lift him again to an upright course."

"You have not much faith, then, in example," said she.

"It is more powerful to save than to prevent in youth," he replied. "How important, therefore, is your work to so fill the boy's mind that there shall be a choir invisible within him when the temptation comes!"

Philip's mother, you know, is of the Roman matron's type. Perhaps this instance will illustrate what I mean:

She is treasurer of a charitable association, and on a late occasion Philip accompanied her to a meeting of the association. After the meeting she suddenly discovered, while they were waiting for a car, that she had no money.

"Why, mother," said Philip, "you have the contribution which was received at the meeting. I saw the silver pieces which you put into your bag."

"That is not our money, Philip. It belongs to the society, and it would be stealing to touch it. We must walk home."

And walk home they did—a distance of four miles—in the rain which was falling.

The boy caught a severe cold; but the mother, bending over his sick-bed in tender solicitude, proudly defended her action: "Honour before life."

III.

Another daily task of Philip was what he called a dose of a German newspaper. I subscribed for a copy of a daily German paper which is published in New York, and I required Philip to look it through every morning, advertisements and all. He was not required to give more than ten minutes to the paper; but those ten minutes were required every week day in the year. He was asked to pick out what he could from the paper without the use of a dictionary, and while I read the morning paper I asked him if such and such an item of news was in his paper.

Here again the schoolmaster told me that it was proposed to devote three months of the curriculum to the study of German. I remember, Richard, how we once arrived at an epoch where a three months' course in German was served up, and how we plodded slowly after a while through Schiller's Wilhelm Tell, and were completely helpless before a German paper, or any other author save Schiller.

My neighbour Stifton's son, now in college, told me that he expected to take up German during his junior year. I asked him why he did not study the language during his summer vacation. You should have seen his countenance; he instantly betrayed his weakness of resource by saying that he could not get a teacher during that time. I prescribed an everyday dose of a daily German newspaper without the use of a dictionary. He, however, had so long been ministered to that he had not the self-reliance to set up for himself.

The practice of reading a German newspaper every day is one of the best ways of acquiring a reading facility with the difficult language. The same words continually recur, and the events of the day force themselves upon your attention, even from behind the heavy curtain of the German language.

I suggested also to Philip that he should read a German Testament without a dictionary, for his familiarity with the English version would supply him with a German vocabulary. The study, too, of the German would incline his mind to rest longer upon the maxims of the Testament.

I selected the German language for this experiment in education, for I felt that, if Philip should take up any profession in which a knowledge of science is necessary, a reading acquaintance with that language would prove indispensable. Then, too, I relied upon his training in Latin to help him in French, Italian, and Spanish. I, too, took my morning dose in the German paper, and Philip and I often had a hilarious time in trying to make out the sense of the various items. He wrote down what he imagined was in my mind after reading the German words, and I, in turn, wrote out my conception of how much he comprehended.

I shall have occasion to mention Schoolmaster Brown in these notes. You must not consider that he was entirely my enemy. I found him grateful to me for giving some individual attention to my child, for he said, somewhat roughly, that parents dumped their children upon him and washed their hands of responsibility. He visited me one evening in a very moody state and wanted to know if I would serve on the school committee—not that he had any power to get me on the committee, far from it; but I of course could manage to become a committeeman. I told him that I did not know how to teach other people's children, for I was only learning to teach my own boy. The schoolmaster looked steadily into the fire and told me some of his troubles. The school committee came into the school perhaps twice a year, with preconceived notions of how teaching should be done. Certain vigorous individuals pointed out what ought to be accomplished, and deplored a certain lack of energy which they noticed, and then they made their bow, and published exhaustive reports containing many suggestions. Meanwhile the school teacher had the incessant daily drudgery of carrying a dead weight of children who had no home teaching.

"Human strength," said the school teacher, "is not equal to the task of individual instruction in school such as you are giving your boy. We must have something similar to a Latin grammar and a Latin dictionary to keep the immature mind at a sufficiently hard task for a long period, otherwise you will kill all the teachers."

"I agree with you," said I. "The parents shift their responsibility; and, believe me, I do not underrate your systematic instruction in the Latin language, which should, it seems to me, be the foundation of every man's education. We, however, do not agree on the value of unsystematic education such as I am trying to give Philip." Mr. Brown, having obtained some sympathy from me, was less inclined to criticise, but I saw clearly that he deplored the formation of bad habits in drawing and in the acquisition of a language. I said: "It is necessary, first, to make a rough track through the wilderness. After this is accomplished, then come the fine lawns and the cultivated gardens." Brown sadly took his hat after this somewhat poetical simile and departed. I felt how unequal I should be to undertake his daily task—the management of a number of other people's children; and I could readily understand how my daily enthusiasm would die out before the deadly dulness of the routine. The school teacher needs our utmost sympathy. My neighbour Stifton says that these teachers and professors are lazy dogs; they have little of the stress of business and professional life. You should have seen Professor Scribain's indignation when I repeated this remark. "Let him take my place as lecturer," remarked the professor, "and after he has put his life blood into an effort to explain a difficulty, let him see his son take out his watch and indolently gaze out of the window. Then comes a subtle blow to the nervous system which calls for renewed effort, and the lecturer feels completely exhausted after the lecture, for he has called heavily upon his mental and nervous resources. Let him take my place for a year, and we should see a less bumptious, uneducated American."

Schoolmaster Brown did not relinquish his attempts to prove that Philip could make far greater advances by taking up systematic instruction in drawing and German during set periods of the year under competent instructors.

I liked that term competent. He tried to prove that the careful rendering of every line in Schiller's Wilhelm Tell, with the aid of the grammar, would in time permit Philip to make a great intellectual leap over the difficulties of the language. I had known, however, so many of our chums who had had this kind of instruction, and could not read a word of a German newspaper, that I was sceptical, and I kept requiring what Philip termed his "morgen" dose. It was true that he had difficulty with the accent, but I got a German in our business to give us the correct pronunciation of the words. One of our amusements was to speak a page of German into a phonograph, such as my clerks occasionally employ in the office, and then see, when the machine reproduced our speech, if we could understand ourselves. This afforded Philip unusual amusement. The phonograph is a deadly, nasal affair, but it shows you a caricature of your faults of elocution, and I found it serviceable in this respect.

I am convinced that Washington's early training in surveying, and the field work connected with it, were of the utmost service in his subsequent career. It enabled him to form a mental picture of the lay of the country and the possibility of erecting commanding fortifications. His mathematical training also contributed to those habits of order which formed such a prominent feature in his character. I took care to impress this characteristic of his hero upon Philip. When the latter, too, was disappointing and somewhat exasperating—I do not wish to conceal this from you, my dear Richard—I took to reading Washington's letters, written from Cambridge in that winter of 1775, in which he describes his disappointments and hindrances. I remember on one occasion Philip brought me for his drawing a simple round O of large size. I really believe my historical reading prevented an explosion on my part which might have imperilled my authority. You will remember that Washington's officers came back from an endeavour to raise troops with round O's, and the Father of his Country is not reported to have said anything.

In furtherance of my design of constantly working with the boy, I bought a camera, and we began by a perfect slaughter of dry plates. I saw, however, that photography might serve as a means of training the eye to observe lights and shades. We soon began to consider how much light there was in and about an object before we sought to take a picture of it, and then we began to see reflected lights which were unsuspected before. I think we neither knew the difference between shadows and reflections until we took a picture of some cows which were standing on the brink of a pool, mirrored completely in the water, with their shadows thrown on the grassy slope of the bank.

Philip, in the first moments of enthusiasm, was for immediately giving up drawing and taking to photography. A photograph was so much truer to Nature than a drawing! I asked him if he would substitute photographs for all the pictures in the fine-art museum, and then he wavered somewhat.

IV.

PHILIP had reached the age of fourteen before I undertook to teach him to reason about the phenomena of natural forces, such as gravitation, electricity, and magnetism. The fundamental conceptions in mechanics are extremely difficult, and I found constant difficulty even at my age in getting a clear conception of the problems involved in a moving train or a cannon ball. The boy's training had hitherto been in the direction of persistent effort in observation by means of drawing, persistent effort in comparing the meaning of words in two or three languages. I do not speak here of his systematic school training with Schoolmaster Brown. This was of the usual nature—a valuable drill in Latin, with a somewhat doubtful training in arithmetic, together with certain other elementary studies.

You desire me to especially relate the story of my own efforts to help the intellectual life of the boy, and I shall therefore proceed with my story, hoping that I have made clear the efforts of Philip's mother and myself to fill the boy's mind with lofty ideals and stories of great endeavour, which should constitute a species of savings bank, upon which he could draw when the exigencies of young manhood demanded. He had seen the value of persistent effort, for the few moments he had spent each day in drawing and reading German had made him facile with his pencil and ready in translating the foreign language. Indeed, these acquirements were so much out of the common course that people not knowing the value of sustained effort thought that he was a genius.

At the age of fourteen we began together to study physics, and one of my first efforts was to teach him the properties of water.

I finally hit upon this simple method of showing that a body is buoyed up in water by a force which is equal to the weight of the water that the body displaces. I fear that I am not using accurate scientific terms, for Schoolmaster Brown tells me that the term buoyed up is not a correct one, there is no force of buoyancy. However, I find it gives me an idea of some force that supports me when I am swimming. This supporting force, I proved to Philip, is equal to the weight of the water which my body displaces. He apparently did not grasp the entire meaning of this statement until he had repeated the experiment, which cleared up my own confusion of mind in regard to this point. This was my experiment: I took a wooden rod about three feet long and half an inch in diameter (a walking cane would have answered); then, taking two ordinary thin tumblers, I tied strings around them in such a manner that I could hang them on the rod. I then tried to balance the rod on my forefinger by suitably moving the tumblers. It was speedily evident that if I balanced the rod without the tumblers my forefinger must be at the centre of the rod—that is, if the rod were uniform in thickness, and if every part of it was of the same density. When I slipped the tumblers on the rod it was evident that they should be placed on opposite sides of my forefinger and at equal distances from it if I hoped to balance the rod with the added tumblers. I then filled one of the tumblers half full of water. The rod, of course, immediately tipped on the side which was heavier. Then I brought a dish filled with water beneath the tumbler, and raised or lowered the rod which still rested on my forefinger at the same point until the rod remained horizontal. The tumbler half full of water was evidently buoyed up in the vessel of water. I noticed how far this tumbler was immersed in this vessel, and then I filled the empty tumbler on the other side of my forefinger up to the same level, and then lifted the rod on my forefinger. When the tumbler left the vessel of water the rod remained horizontal. It was evident that the tumbler in the vessel of water had been buoyed up by a force which was equal to the weight of water that had been displaced by the tumbler, for, on adding this weight to the empty tumbler, the rod rested in a horizontal position.

I confess I was delighted with this experiment, and I made Philip repeat it. He was more or less critical in regard to it, and tried to prove that I moved my forefinger during the experiment; but I got him to investigate what would happen if the forefinger should be moved, and he immediately suggested that it would be an improvement to cut a notch in the rod, and support the rod on the sharp blade of a jackknife, in order to prevent any slipping. He also pointed out that the thickness of the tumbler might make a difference in the result of the experiment. I acknowledged that I had neglected to take into account this thickness, which, however, was small. I then said, "Doesn't this experiment suggest a method of finding how much one is buoyed up in salt water?"

"Yes," said he, with a laugh; "if you will get into a tumbler, I will balance you by adding water to a tumbler on the other side of the balance rod."

"Of course," I replied, with philosophical gravity, "that is impossible. Couldn't we manage to balance a plank on the stern of a boat in some way. When either of us got into the water we could catch hold of the end of the plank and the other could balance it by crawling along the plank in the boat until it was again horizontal."

This plan pleased my youthful critic immensely. I believed at first that he expected considerable fun, but I set his mind to thinking on the serious matter of ascertaining by this experiment what he wanted to know—that is, the weight of the amount of salt water that our bodies would displace, for the experiment with the tumblers showed us that this weight would be the force which would buoy us up. He could not reason out the experiment in a perfectly satisfactory manner, and he resolved to take a plank the next time he went in swimming and try the experiment.

Philip was just learning to swim, and had not gained complete confidence in his power of supporting himself in the water. Accordingly, on the day of the experiment I resolved to enter the water and leave him in the boat. We were both in our bathing suits, prepared for an overturn of the boat, which, however, was not much to be feared, for it was a commodious one and broad of beam. Before pushing the boat off from shore, we amused ourselves in balancing on a plank in a seesaw fashion. I really felt the spirit of youth in me again as I scrambled back and forward to avoid the bumps which Philip was desirous of giving me. I think he got the most of the play, for I had estimated the effect of my weight more closely than he had. We were a pretty sight, I assure you, in our bathing suits, wildly balancing ourselves, one a middle-aged man and the other a scrap of a boy. However, the end of it all promised to be philosophical. Philip weighed eighty-five pounds and I weighed one hundred and sixty. So he had to crawl to the end of the plank to balance my weight, which was nearer the point of balancing of the plank. When this balancing was accomplished I said: "This is all very well, but we want to imitate our experiment with the tumblers. I will attach a rope to my end of the plank, and when I am in the water I will catch hold of the rope and let myself sink until the water comes up to my eyes, and we will see what will happen."

Accordingly, we pushed off in the boat and proceeded to a place where the water was a trifle over my head. I got into the water and, catching hold of the rope which was attached to the end of the plank, tried to lower myself until the water should come up to my eyes. Philip's weight, however, prevented this. I could not get my head down to the level of the water, and I was compelled to tell him to get off the plank.

"You see, Philip," I said, "my weight is almost exactly equal to the buoyant effect of the water, or to the weight of the water which my body displaces. I don't need your weight on the plank to balance me."

Philip looked at me as I floated with my nose just out of water.

"What makes people sink?" he asked.

"They get frightened," said I, "and allow water to enter the body and expel the air. If they realized what this experiment shows, they would not be drowned, for they could float with the mouth and nose above water, as you see."

"You look uncommonly funny," said Philip.

"Suppose you let me look at you," I replied.

Philip acknowledged that this was no more than just. He accordingly crept out on the plank until he balanced my weight, and then taking hold of the rope he lowered himself into the water. My end of the plank went down, for he was buoyed up by the water which he displaced.

"You will have to get off the plank," he cried, "for I am buoyed up to such a degree that I can't get my head into the water."

I cautiously got off the plank and had the satisfaction of seeing my hopeful floating with great confidence with his mouth and nose just above the surface of the water.

When he got into the boat I was about to suggest that he had looked uncommonly funny; but at our age the laugh should be left on the side of youth. The wind having risen, Philip proposed that we should take a short sail, and, having dressed ourselves, we set our sail and were soon slipping by the promontory of Little Mag. The wind was variable; at times it blew very fresh and at other times there was almost a calm. We noticed the singular fact that there was a streak of wind blowing along the shore while farther out there was almost a dead calm. I was calling Philip's attention to this phenomenon when, all at once, a sudden puff of wind caught the sail and blew the boom up against the mast, and over we went. We speedily came up on opposite sides of the boat and held on to its sides.

"We've got something real to laugh at now," I said grimly, looking toward the shore, which seemed at a prodigious distance now that we were in the water. Perhaps it seemed farther than it really was because I realized that Philip had never swam more than two hundred feet. My anxiety for him was somewhat lessened when I saw him lift himself out of the water and scramble upon the upturned keel, where he sat with his bedraggled curly locks covered with a dripping straw hat. Presently a fog set in and I began to fear that we might drift out into the open sea. We could not have been in this perilous situation longer than ten minutes—it seemed half a day to me—before I heard the click of oars in the rowlocks and a longshore fisherman loomed up in the fog. He was standing up in a dory, rowing it in this position, looking toward the bow, in which was a collection of lobster pots. I immediately shouted to him and he came to our assistance. As he approached, Philip took off his straw hat and made him a low bow. The fisherman remarked dryly:

"Hadn't you better get in?"

We followed his advice, and while he was rowing us to shore I explained how the accident had happened. He was evidently a man of few words, and his only comment upon the affair was this:

"Guess your sail made a goose-wing."

I said to Professor Scribain one evening, after a week of discouragement in home education: "It is astonishing how difficult the so-called elementary principles of physics are. I find I can impart to Philip only an extremely small portion at any one time. Indeed, I can receive myself only an infinitesimal amount of such strong food." The professor gazed at me over his spectacles with a beaming look of sympathy.

"I have lectured on physics for forty years," he remarked, "and I am firmly persuaded that the doctrine of homœopathy applies better to physics than to physic. In order to hold the attention of an audience you must administer truth in infinitesimal doses, with plenty of dilution. Moreover, I have come to the conclusion that lecturing is an uneconomical process in education. Individual instruction is what must be arrived at. The instruction you are giving your boy is priceless. Personal influence and individual instruction, these are the great forces in education. I formerly asked myself: Why do I feel so utterly exhausted after a lecture? The subject is familiar to me. I am not trying a new case before a supreme bench—I am easily the master above my audience. It is true that the preparation of the experiments is somewhat arduous, for pieces of brass and glass are apt to oppose one's progress as if they were the implements of a physical devil bent upon throwing obstructions in the way of a searcher after truth. Yet one gets in time to expect a resistance from rude matter; this resistance does not stir up the nervous element in one like the resistance opposed by human nature to pure reason. Why should I, after one or two lectures a day, feel as if I had done a full day's work? My friends the lawyers laugh at me, and point to their strenuous endeavours. They often work till midnight in one city and take the night train for another metropolis only to enter another court room. I am a lazy dog, they say.

"Well, I have submitted the matter to examination, and I find that the fatigue comes from several causes. In the first place, while lecturing in the full flow of enthusiasm, my eye lights on a young man, with pendulous lower lip, whose eyes are set with a vacant stare on some object outside the window. While my nerves are in a state of tension I hear another student wind his Waterbury watch. I am led to labour harder and harder, with the dull consciousness that I am doing all the work, and the work is making little impression. When a nerve is fully strained it can be badly injured by a new strain. The truth is, lecturing is in most cases labour wasted, except to men who have had individual instruction on the subject, and who come together with an interest in the subject and some knowledge of it. Lecturing to an audience that has never studied a subject is a waste effort. Moreover, the state of mind of many of the listeners is immoral: they expect to get something without working for it."

"How would you give instruction to large classes?" I asked.

"I would set the members of such a class to work in small sections, looking up the subject, carrying out some laboratory method or critical inquiry. I would occasionally have a round-up, just as is done on the plains with the herds; but the work should be done every day by the students themselves, and not three times a week by the professor. After you have done your best in a lecture some one will say: 'A very interesting subject; I did not, however, understand it.' Of course he or she didn't. They had never taken the trouble to study it; they had not acquired the power of sustained attention. Such remarks make a professor's limbs tremble after an hour's strenuous effort, and conduce to his low state. Then some popular lecturer appears on the horizon, and you go to hear him and listen to popular statements, in which the real difficulties of the subject are concealed and the audience is amused. No; lectures are intellectual dissipations. What we must have is individual teaching and sustained effort. You are right in demanding a little every day. The psalmist says, 'Come, let us reason together.' This injunction implies that the reasoning should not be done by one side alone."

V.

I SAW in our plan of making suitable golf grounds that there was an opportunity of studying together with Philip some simple problems in surveying. I was ignorant of the subject, for I had merely attended a course of lectures on trigonometry while in college, and had forgotten the little information I had obtained. I presented the somewhat lamentable spectacle of a man of middle age puzzling out the rudiments of a subject which I should have mastered in my youth. There was, however, this element of advantage in my apparent position of disadvantage: I was not so advanced as to forget the difficulties of the mind untrained in the particular subjects. In struggling with these difficulties I was on the intellectual level of Philip, and we could face the difficulties together. So it seemed to me that the problem of making a survey of our proposed golf grounds would be an interesting one for us to study together. It was highly desirable that parts of the grounds should be well drained, for there were many springs, which kept several acres in a very moist condition, and I had an indistinct notion that a careful survey would show us in what directions we should endeavour to drain the wet land.

I confess I had to overcome considerable mental inertia in approaching the problem, for the charms of the daily newspaper and the attractions of the host of magazines which our book club poured in upon us, together with a sedative cigar, made the effort of studying methods of surveying seem almost insurmountable. I saw, however, so many of my business friends who had no interest in anything except business, who had lost the faculty of enjoyment except in very limited ways, that I determined to brace up and to obtain a new interest; for one way, my dear Richard, to secure contentment of spirit, if not happiness, is to keep the mind fully employed. I had to begin at the very rudiments of geometry in order to prepare myself for the business of surveying, and I began by making a grand discovery, which, as is usual in such cases, had been made before. It was a method of studying geometry and trigonometry by what may almost be called pleasant puzzles, of which our survey of the golf field was a good example. You will find the method fully described in a little book written by the father of Herbert Spencer, termed Inventional Geometry. I had the immense satisfaction of feeling for a while that I had made a discovery of a new method in mathematical education, and the further satisfaction, in the downfall of my intellectual pride of feeling, that I had actually touched the high plane of a thinker and father of a philosopher for one brief moment.

This was the humble way in which I satisfied myself that we could get the number of square feet in our golf field if we could divide it into triangles and sum up the area of each one of these: I sent Philip to the post office for a dollar's worth of two-cent postage stamps, telling him to be sure to bring me fifty. When he returned I asked him how he knew that he had fifty. His politeness almost gave way at this question.

"I counted them."

"Did you count each one, or did you multiply the number on one edge of the strip by the number on the adjoining edge? There should be ten on one side and five on the adjoining edge."

Philip was forced to confess that he had counted each one, and he immediately put in practice my suggestion, saying, "That would have been shorter."

"If our golf field were shaped like this strip of postage stamps, it would be very easy," said

I reflectively, "to get the number of square feet. We could multiply the number of square feet on one side by the number on the adjoining side. The square feet would take the place of the postage stamps. I have it," said I with enthusiasm; "this strip of postage stamps can be cut into two equal triangles; therefore the number of postage stamps in such a triangle would be one half the number in the whole strip, or you could obtain the number by multiplying one side by half the other side."

Philip pointed out somewhat maliciously that a number of the stamps would be cut by such a division.

I proposed to him to make a Chinese puzzle out of paper which would prove that the area of any triangle is equal to the half of a strip similar to the strip of postage stamps in which the sides are perpendicular to each other. We spent an evening over this puzzle, and I confess with some mortification that Philip's mother was the first to solve it. And this was the way she adopted: Having cut out of paper a triangle which Philip drew for her, she made an equal one by tracing the outline of the first on paper and then cutting this one out. She then put them together with their longest sides against each other, producing thus a parallelogram (Fig. 1). She then cut off one corner of this parallelogram, *A B C*, and slipped it to the opposite corner (Fig. 2), where it occupied the position *D E F*.

"There," said she, "you now have a square strip *B E F C* like your strip of postage stamps, and, since one of the triangles was half the figure before I cut off the corners in this manner, it must be one half of what you call the rectangular strip which I have now made."

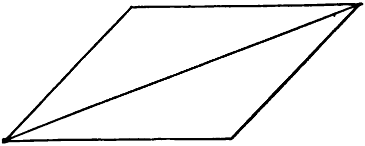


FIG. 1.

We then discovered that the straight line which Philip's mother cut was the shortest distance between two parallel sides. The area of either triangle was then equal to one half one side multiplied by this shortest distance, since the area of the rectangular strip was equal to the whole of this distance multiplied by the adjoining side.

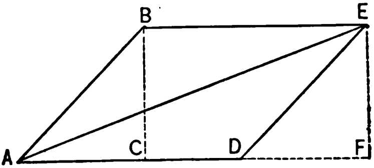


FIG. 2.

I have been prolix in describing to you at such length this method of studying geometry, for it seems capable of more universal application. I remember that I hated geometry while at school, but I now see that it can be made an amusement. It was evident to the family that if we could divide the golf field into triangles we could readily get its contents in square feet, by adding together the contents of the triangles. Philip and I first made a rude estimate or guess in regard to the number of square feet in the field. His estimate was perfectly wild, and I confess that mine was equally so. We found out that there are 43,560 square feet in an acre, and Philip thought there might be one hundred acres. I knew that this was impossible, but we set out, anxious to convict each other of an error. I have discovered that, although a boy has great deference for a father's opinion, he is sometimes loath to express it, and would like mightily to convict him of an error. This is the growing strength of a young giant—the pushing forward of the teeth of the lion's cub.

I suggested to Philip that, having first ascertained the average length of our steps, we should pace around the boundaries of the field, and, having in this way obtained the lengths of the sides, we should then divide the field into two triangles by pacing from one corner to the opposite one.

You know the field, Richard; it is the large tract with four sides lying back of the Perkins woods. Well, Philip and I spent some time in ascertaining the length of our average paces. We measured the distance we paced in ten and twenty and thirty steps, and found that the length of my paces averaged two feet and six inches, while Philip's paces averaged two feet. We found that there was little difficulty in keeping to the boundaries of the field. But when we undertook to walk across the field from one corner to an opposite one, in order to divide it into two triangles, we wabbled, as Philip expressed it. I therefore stationed myself at one corner and, looking across the field to the opposite corner, I asked Philip to take a position in the field on the line between the two corners. I placed him accurately on this line by sighting past him to the opposite corner, and motioning to him by waving my arms until he came into the right position. I then paced up to him, and, having reached him, I sent him forward again to take up a new position between me and the corner I was desirous of reaching. In this way I did not wabble across the field, and I measured with fine accuracy the distance across the field. Phillip repeated this measurement, and I took his former positions. That evening we made a map of the field by means of a foot-rule; we let one inch represent two of Philip's paces, or four feet, and we laid off a line representing the longest side of the field. We then took a thread and measured off a length equal to the distance across the field, added to the length of the side next to the longest side. That is, in the sketch I send you Fig. 3), *A B* represents the longest side and *B C* the side next to it, we took a thread equal to the length *A C* added to *B C*, and, having fixed the ends of the thread at *A* and at *B*, we stretched the thread tight by means of a pin until we made the pin divide the thread into the lengths *A C* and *B C*. The point *C* was then one of the corners of our field on the map. Then drawing the line *A C*, we fixed the ends of a string at *A* and *C*, and, making it equal in length to the sides *A D* added to *D C*, we stretched it tight and thus obtained the corner *D*. Then we had a map of the field. Each one of the triangles was one half of a parallelogram. We constructed these parallelograms by cutting out the

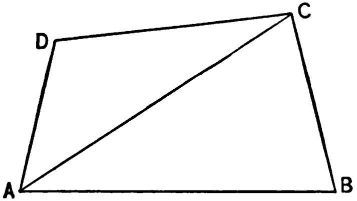


FIG. 3.

triangles from paper and duplicating them; and we found the area of the triangles by multiplying one side of these parallelograms by one half the shortest distance between them—just as Philip's mother had shown that we could do. We found in this way that the field contained 871,200 square feet, and on dividing this by 43,560 we obtained twenty acres. We had the satisfaction of knowing that our golf field was larger than that of the Newtown Club. This knowledge was much prized by Philip. A boy generally likes to have something larger than anything possessed by his acquaintances—it answers fully as well if he feels that his father has it.

I told Philip that we ought now to measure the field with a tape line, for it would be of interest to see how much of an error we made by surveying it by pacing around and across it. On calculating again, we obtained twenty-one acres, and we were pleased that we were so near right in our first estimate.

Do you remember, Richard, our instruction in geometry at school? H., the head teacher, used to make us file up to the blackboard in military order, and distribute geometrical problems to us much as cartridges are given to soldiers; and then we fired off our problems, having carefully drawn figures on the board exactly like those in the book, and having printed *Q. E. D.* —*Quod erat demonstrandum*—in large letters. You probably understood what you were doing, for you were brighter than I; but I confess to you, as I have confessed before, that I learned the propositions by heart, and had no more notion what they really meant than if they were inscriptions in Sanskrit. I really believe that the teacher would have been at his wits' end if he had lost the geometry. It is said that geometry now is much better taught than formerly. I have discovered pretty late in life that the study of geometry by practical applications is a fascinating one, and one can drive away many hours of *ennui* by occupying one's self with it.

Well, Philip and I found out how many acres there are in our golf field. I then proposed to him that we should drain the marshy portions of it. Where to run the drains was a serious question. I told Philip that if he would make a model of the field in clay, representing the hills and the depressions, we could form an idea of how the drains should run. So Philip got a batch of clay from the pottery in a neighbouring town, and, having spread it on a board, endeavoured to represent the surface of the field. We could not agree upon the direction of the slope of the field. While we were talking the matter over, our old gardener, who had watched our field operations with a cynical air, and who had heard our discussions of the probable direction of the underground flow of water, remarked that he had a friend who could tell us just where the stream flowed beneath the soil. It is astonishing how the world is set upon breaking up any pet scheme one may have to educate one's son. My neighbour Stifton's boy, of whom more anon, had repeatedly appeared on the scene with a baseball bat, greedy of all the hours in the day, and now the gardener was desirous of showing us that we were wasting our time. I told him to produce his man, for I thought that he might have some practical method which would be instructive.

The next afternoon the gardener came to the golf grounds, accompanied by a tall and lanky individual with a long beard, who had a forked stick in his hand. This individual told us that he could ascertain the locality of springs and the direction of underground currents of water by the pointings of this forked stick. I was for denouncing him before Philip as a humbug; but I restrained myself and was curious to see what the boy's impressions would be of the man's assumptions. The man strided over the field, grasping the forked stick, which he informed us had to be of witch-hazel, although he had known of an apple-tree twig working. We presented a curious spectacle as we wended our way—the water-finder in front, with a portentous air, followed by the gardener, led a willing captive, and then Philip and I, while the neighbour's boy and the baseball bat brought up the rear. I have seen pictures of similar processions, I believe, in "Darkest Africa."

The individual with the forked stick was a shrewd old chap who took in the lay of the ground, and his weapon swayed to and fro and pointed out the best direction for drains in due accordance with the general character of the ground. I led him toward a region where some years previously I had had a water pipe laid which connected a distant spring with my stable.

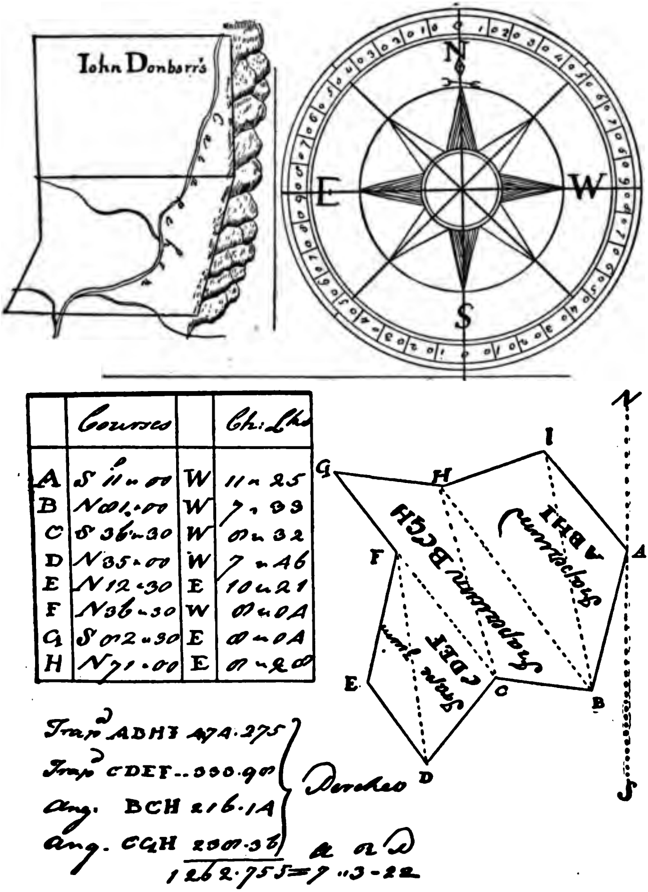
"Do you find any water in this region?" said I with an innocent air.

The water-finder looked at his forked stick and cast a shrewd glance to right and left. The immediate region was a little knoll over which the pipe had been conducted, but beneath the surface.

"No," he remarked, "the stick does not turn."

I dismissed the gardener's friend with thanks, and resolved to enlighten Philip in regard to the time-honoured superstition of the wand for finding water after we had found out for ourselves the best positions for the drains.

I have referred to the small boy with the baseball bat, with some intimation that he was a disturbing element that had appeared on the horizon. Philip's schoolmates in the town school seemed to be good fellows. He met them during school hours, or, when they accompanied him home, they did not stay long. This neighbour boy, however, was like an August fly, and I confess that I was annoyed. It is extremely important that a boy's early playmates should be good fellows, for the old, time-honoured saying that "evil communications corrupt good manners" applies with especial force to boys. We know this, Richard, from our own experience. Philip's mother said that she had little fear, for it was for this epoch that she had filled her boy's mind with thoughts of great actions and noble men. I felt comforted by her confidence and resolved to enlist the young baseball enthusiast in our attempts to survey the field; but he was off in no time, scenting a schoolmaster in me. A large part of Philip's soul went with him, and I therefore did not push my surveying experiments very fast, but told Philip the story of General Washington's career as a surveyor when he was a young man, and Virginia was bounded toward the west by almost unbroken forests. What charm there was to that boy in everything connected with Washington! I could hold him hour after hour with accounts of that hero. The boy knew of Washington's conduct at Braddock's defeat, his passage of the Delaware, his winter at Valley Forge, his struggle with treachery and with the waning courage of those about him; but he had never heard of the life of Washington as a surveyor. I had never myself known anything of Washington in this capacity, and, having had my interest in surveying suddenly aroused by my endeavour to study the subject with Philip, I turned to the early records of Washington's life. It seems that the profession of a surveyor was a highly honourable one in the early days of the colonies. It demanded an education which was far from common, and, moreover, it required strong physical qualities, such as endurance and courage, for there were miles of trackless forests to be mapped and hostile Indians to be encountered. The surveyor, too, was an enterprising man, who had the opportunity of judging of the best locations for settlers. I endeavoured to picture to Philip Washington, as a young man, running lines through the forest, sometimes with only one companion, sleeping before great camp fires at night, one guarding while the other slept, occasionally getting lost in woods where one scene was reproduced by another until confusion led to the certainty that the trail had been lost and it was necessary to climb some lofty tree to look over the wilderness and detect some landmark. I discovered that Washington had only two surveying instruments—a compass and a surveyor's chain—and I set to work to learn how he used a compass. It was really absurd how difficult I found it to comprehend how the young man Washington surveyed. I came across a map drawn by him when he was perhaps nineteen, which had in his remarkably clear and precise handwriting all the data, and before showing it to Philip I pored over it for many hours. Understand it I must, for to be floored by the Father of my Country before he was twenty was too much. Here is the map. You will notice that he puts down the bearing of each line of his survey and he gives the lengths of the lines in rods and perches. I found from an old arithmetic that a chain is four rods, or sixty-six feet, and a perch is the same as a rod, or sixteen and a half feet; but what use was the bearing of the lines, and what is the bearing of a line? I soon discovered what it meant, without asking questions of Schoolmaster Brown, which I was tempted to do. The compass used by Washington was something like a rifle with two sights. The compass dial shown in Washington's drawing was mounted on the middle of the rifle and the latter supported on a tripod. In order to get the bearing of a line, one, having put the centre of the tripod on the line, directed the sights so that they


John Donbarr's
N
S
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	Courses		Ch: Lk
A	S 11..00	W	11..25
B	N 001..00	W	7..33
C	S 36..30	W	00..32
D	N 35..00	W	7..A6
E	N 12..30	E	10..21
F	N 36..30	W	00..0A
G	S 012..30	E	00..0A
H	N 71..00	E	00..200

Trapd ADHI A7A.275
Trapd CDEF..330.900
Ang. BCH 216.1A
Ang. CGH 2300.36
1262.755 = 7..3..22

Perches

a r p

FIG. 4.—FACSIMILE, COPIED FROM A MANUSCRIPT IN THE HAND-WRITING OF WASHINGTON. ÆT. 16.

should cover two points along the line, and then the inclination of the line from the reading of the compass gives its bearing. The compass always points north and south, and the deviation of each line of the field from the line north and south gives its bearing. At sea, for instance, the sailor speaks of an object bearing due east, or so many degrees from the north end of his compass—ten degrees north-northeast, for instance. All at once I understood how Washington surveyed. He got the bearing of a line of the survey by placing his compass over the starting point of the line and then looking through the sights until he covered a distant point on the same line; the deviation of the compass from this line of sights was the bearing of the line. If he should proceed along this line, the compass needle would always make the same angle with this line. He then measured the length of such a line and entered it in his note-book opposite the bearing. For instance, Fig 4, the bearing of the line *A* to *B* was southwest eleven degrees, and the length was eleven chains and twenty-five links, or seven hundred and forty-two feet and six inches.* When he got to the point *B* he set up the compass at *B* and sighted to *C*. The deviation of the line *B C* from the direction of the north-and-south line of the compass was eighty-one degrees and the length was seven chains and thirty-three links, and so on. After the survey he made a map by drawing a straight line to represent the north-and-south line of the compass, and, starting with a point *A*, he laid off in degrees the deviation of the line *A B* from the north-and-south line. To do this he must have made use of a scale of degrees or compass card (as shown in Fig. 4). I found that these could readily be obtained even in the time of Washington. At present they are made of a thin, transparent, horn-like substance in the form of a half circle, which is divided into degrees and minutes.

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* A link is the one hundredth part of a chain.

The operation of surveying, as conducted by Washington, was really a very simple matter, and I took the following method of explaining it to Philip: I had a light drawing-board made which I could screw upon the tripod of his camera, and I fixed two uprights on this board opposite to each other at the end of the line which passed through the centre of the board. These uprights had small holes at the same height through which one could sight. Then I placed a little pocket compass on the middle of the board, between the two sights. With this apparatus I sallied out, telling Philip that we would resurvey our golf field after the manner of George Washington, and we would imagine that we were in Virginia in the old colonial times, and that there might be Indians lurking in the woods back of the golf grounds, just in the direction of neighbour Stifton's house.

We got the bearings of the boundary of the field famously, and when we returned to the house it did not take us long to make a map of the field, just as Washington might have done.

VI.

I EXPRESSED my opinion that Washington's physical endurance during the trying scenes of the Revolution was greatly due to his long tramps in the woods while he was pursuing his vocation as a surveyor. I believe, my dear Richard, that if the young athletes of the present day should engage in feats of endurance rather than in feats of strength they would secure for themselves a much longer life. The struggle of life demands physical and mental endurance, and the occasions when a young man has to lift his sweetheart out of a chasm with one arm arise only in novels. Philip has now the idea, which comes to every boy, that he must cultivate his muscles, and I encourage it; but most of the boys of his acquaintance indulge in sports to an intemperate extent. Philip's mother wavers a little in regard to my restriction of his sports, and says she fears that he will be regarded as a singular boy by his comrades, and that he will lack companionship. I have great faith, however, in the effect of character, and I believe that Philip's home training will make him respected. Moreover, I do not relish the idea of having boys of that age influence the parents to such an extent.

I write to you, Richard, this full account of my experience in studying with Philip, and I should not conceal that I had often to exercise all my powers of nervous endurance and patience. It would have been so easy to omit the demand for the results of his ten minutes' study of the German newspaper, or to pass over the occasional neglect to hand me a drawing every day. I was determined, however, to teach him what could be accomplished by constant attempts which required but a few moments each day. This is such a valuable lesson that I felt that if I could inculcate it I could make the future man's career. I therefore did not allow moments of weariness and days of business exasperations to interfere with my plans.

In my endeavour to study the art of surveying with Philip I was aided by his faculty for hero worship, which had been cultivated greatly by his mother, and I believe also by his pictorial surroundings. Washington, I have said, was the greatest of heroes to the boy, and he was anxious to be able to do what Washington did when he too surveyed fields. I confess that I also shared Philip's admiration for Washington, and I felt a peculiar satisfaction in being able to understand

Washington's survey of which I sent you a sketch (Fig. 4).

Having some relatives in Virginia, I wrote to them to ascertain if there were any traditions in regard to Washington's boyhood and young manhood which might interest Philip. I could not learn much which is not set down in the histories of colonial times. Accounts were sent to me of certain incidents in his experience as a surveyor which illustrated his energy, persistence, and courage. I could trace from these family records the field of his work as a surveyor in the trackless wilderness, which at that time extended from the foot of the Blue Ridge and the Alleghanies toward the great and fertile tracts that lay on the western side of the Ohio. In surveying through the forests it was customary to blaze the trees—that is, to cut a mark on the bark in order that the way should not be lost in a forest where one nook strangely resembled another, where the fallen tree trunk, covered with moss, gigantic in size, and fit for a landmark, had its perfect representation in another. The Indians had no difficulty in finding their trails through these forests, and doubtless the knowledge that Washington gained in this forest work of the habits of the savages was of the utmost advantage to him. If General Braddock had listened to the cautions of the Virginia colonel, his great disaster might not have happened. Among the interesting stories which came to me from Virginia was the following, which served to keep up Philip's interest in Washington and incidentally in surveying: Among the retainers on an old Virginia estate was a family in which there was the tradition that one of the ancestors accompanied Washington on his surveying excursions, and the following story had been handed down, much amplified, doubtless, in the telling:

It seems that on one occasion the surveying party had made a much longer excursion than usual in the great valleys that run between the Blue Ridge on the one hand and the Alleghanies on the other. They had found a pass in the mountains which was a natural curiosity. It was not unlike, I judge, to Crawford's Notch in the White Mountains. On one side was a considerable extent of more or less open country surrounding the marshy sources of a stream which found an outlet through great gates of stone between precipitous mountains and then roared through deep ravines far below in the dense woods which extended toward the misty west. Through this gateway ran a well-defined trail. As the surveying party was proceeding down this path one of them heard a noise which he, being learned in Indian ways, declared was the sound of an approaching band of Indians. A council was rapidly held, and it was decided to seek a hiding place among the rocks which lined the pass above the woods that hung over the roaring brook. The story ran that Washington immediately became the leader, and by his steadiness and courage inspired confidence. The compass and chain were concealed behind a fallen tree, and without breaking a twig or leaving traces of their presence the party sought a refuge. As they ascended the steep side of the mountains they prepared their firelocks, ready for any emergency. At first they made a hasty scramble through the deep moss and thick underbrush, lifting themselves up the heights by the limbs of the trees. It did not take long to get above the tops of the trees, and, seeing that a further climb would fully expose them to a party advancing down the notch, they crouched behind the rocks. The ancestor's account of what he then saw must have caused a thrill in the hearers as they sat winter nights before the open fireplace, over which hung the old firearm and the powder pouch that were carried on that occasion. I could see Philip's eyes grow darker as I read the account to him.

The party saw a file of savages, in full war paint and feathers, tramp down the forest path. They uttered guttural remarks as they advanced; but their heads were not turned to the right or left, and the sunlight, striking through the openings in the wood, lighted up the deadly resolves which seemed to be sealed on their painted countenances.

The surveying party counted as many as fifty Indians moving with stealthy step along the trail, now passing behind the thick branches of the trees, now emerging to full view, where the sunlight brought their savage countenances into startling distinctness. It seemed as if they must become aware of the near presence of the white men. The latter, however, held their breaths, and crouched lower and lower, peering through the crevices of the boulders which sheltered them. At last the Indian file disappeared down the rapid descent, and the concealed party began to breathe freely, when all at once one of them —a long-limbed Virginian—whispered: "There comes a dog; it will make for us." His companions' cheeks blanched as they saw an Indian dog come through the notch in the distance, trotting fast to rejoin the Indians, his red tongue protruding from his mouth. If the animal should catch the scent of the party in the rocks, and should call attention by his bark, the Indians would return. The Virginian who had first caught sight of the dog, closing his fists tightly, said that if the dog came his way its bark would end in a fit of choking. The narrator of the incident said that young Washington counselled great prudence in dealing with the animal; on no account should a firearm be used, and every effort should be made to capture the dog. The party distributed themselves, in order that the taking of the dog might be made more certain.

All this cogitation took but an instant, and the dog had left the trail. Every one supposed that he was investigating the scent of their footsteps, and had already found the secreted compass and chain. But no; he was presently seen lapping the water in a pool of the brook far below them. Then, having taken its fill, they saw it sturdily mount the steep sides of the brook, pushing its way through the thick masses of ferns to regain the trail. Again it was lost to view, and there was an ominous silence. Then a singular yelp was heard. "It's on our scent!" exclaimed two members of the surveying party simultaneously. In the silence which followed this remark there was a sound of rustling leaves. The dog was on the scent! Presently the sound of its yelping was heard as it coursed to and fro through the forest. In a moment it would be upon the concealed party.

It is probable that every one in the party looked at young Washington, who had grasped his rifle by the barrel and was ready for the dog. The rustling noise made by the animal sounded nearer and nearer. Now its claws could be heard scratching the sides of the rock as it sought to lift itself up the ledges by which the party had ascended. The concealed men whispered that the Indians might suppose that the dog was on the scent of a fox; its prolonged barking, however, would attract attention, and might lead to the return of some of the younger braves. It was not long before its breathing could be heard, and in a moment, with a leap, it was over the boulders and among the concealed men. It hardly had alighted in their midst before one of the hunters had thrown a blanket over it and held it fast. Another was about to dash its brains out with the butt end of his rifle, but one of the party (tradition said it was Washington) cried out: "Spare the dog! The poor brute was merely doing its duty."

The dog showed no disposition to resist its captors, and, after a suitable interval, the surveying party cautiously made their way out of their lair, and, with the captive dog, swiftly passed through the mountain notch and made their way to the settlement.

VII.

WHEN we, Philip and I, had thoroughly comprehended Washington's method of surveying, I proposed that we should ascertain what new methods have been employed since his time. I brought home a treatise on surveying, and soon discovered that it presented a very formidable look to Philip, and I felt that he would lose his interest in the subject if he were compelled to study the book. I confess that I too felt a despairing sense come over me as I looked at the mathematical formulæ. I recognised them, for we had had them in college, but it was the recognition of an enemy and not of a friend. There was a chapter, however, on what is called a plane table, and Philip and I got interested in using one. It is really little more than a drawing board, mounted on three legs like a photographic camera, which one takes into a field, and, having pinned a sheet of paper on it, draws a map of the field then and there. We had already rigged a board on Philip's tripod to illustrate Washington's method of surveying with the compass. We now removed this and screwed on the tripod another flat board, and I got Philip to mount two vertical strips of wood at the ends of a flat strip about a foot and a half long. This was our sighting piece. By keeping one end of the flat strip always at a fixed point on the board we could get the range of any point in the field by moving the strip around the centre so that the two verticals should cover the distant object. It was as if we were using the two sights of a rifle, keeping one sight always vertically over a point on the board. By then drawing lines along the side of the flat strip these lines were in the direction of the distant points, and by

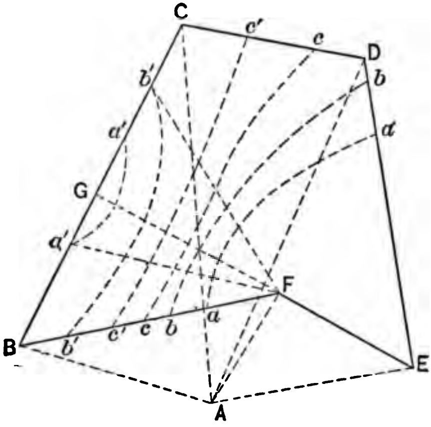

FIG. 5.

measuring the distance from the fixed point to these distant points we could draw a map of a field on the board.

Suppose, for instance, that the point *A* (Fig. 5) represents the point under our first sight. We drew a line in the direction of the line of sight of *B* and laid off on this line the distance *A B*. We then sighted to *C* and laid off the distance *A C*, and in the same way we obtained the points *F*, *D*, and *E*, and connecting these points by lines we obtained a map of the field *B C D E F*. This instrument afforded us much amusement, for we first drew a representation of a field and then made the measurements on our plane table, and fell to laughing over our absurd conceptions of the real appearance of the field.

I got interested in the problem of draining the golf ground in a more scientific manner than my gardener proposed, and I discussed the matter with Philip, with what little light I could glean from a book on drainage. It was evident that we ought to know the relative heights of different points on the field in order to ascertain which way the water would flow, and then which way the drains ought to run.

"If," said I to Philip, "we could float over the field in a balloon always in the same plane, we could let down a rope like a sounding lead and measure the heights and depressions of the field and then make a clay model of the surface. We should in that case be measuring always from a level surface somewhere up in the air."

Philip was captivated by the idea of the balloon; his boyish fancies were all ready to escape from calculation into the indefinite upper regions of space. He was for the moment a philosopher. His experience, however, in flying kites soon made him critical, and the supposition of a balloon resting always at the same height got to be unendurable, and he cried out at the absurd idea.

"It's only a supposition," said I. "We could suppose that there is a great level board up in the air instead of the balloon—a great checkerboard, for instance—and that we drop a sounding lead from the corner of each square on the checkerboard."

"Why couldn't you let the checkerboard rest on the highest part of the field where you could get at it?" said Philip dreamily.

I looked at our plane table, and a method of using it slowly dawned upon me. On the following day I bought in the city a carpenter's level, which you doubtless know is a piece of wood with a little glass tube set into one of its sides. This tube is not entirely filled with a liquid, so that when it is placed horizontal an air bubble rests at the centre of the tube. I could make our plane-table horizontal by placing this carpenter's level on it and moving the legs of the tripod until the bubble of the level always remained at the centre of the level. I then fixed two sights on the level, one at each end, and then by sighting over the tops of these I could be sure that my eyes were directed along a perfectly level line. I then provided Philip with a tall pole which was marked off into feet; and as he moved across the field, advancing along a measured line, I sighted along my level and observed where the line of sight cut his pole, and I made him move his hand up and down until my line of sight struck it. He then read off the number of feet this intersection was above the ground. In this way I got this difference of level of various points along certain lines in the field, and I speedily determined where the drains should run. Philip finally made, by this use of the plane table, a complete contour map of our field, and this was the way he did it: He placed the plane table at one corner of the field—that of *F*, for instance (Fig. 5). He then sighted along lines radiating from *F* and observed the height of the pole at various points on these radiating lines. A line was then drawn connecting the points of the same level. If any radiating line like *F G* should be drawn (Fig. 5), and at the proper distances from *F* perpendiculars should be drawn, a cut through the surface of the ground would be represented (Fig. 6).

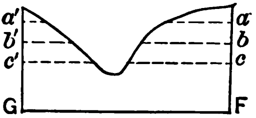

FIG. 6.

Everything seemed to be progressing finely in our work of surveying until one day there came a setback. I experienced the mood which I suppose comes sooner or later to all thinkers and investigators—a mood of depression which succeeds one of elation. Philip greeted me one evening on my return from the city after a peculiarly harassing day with the remark:

"There is something wrong in our survey, for I have measured across the field from one corner to the opposite—not the two corners between which we measured our distance—and I find that the distance is a hundred feet more than it measures on our plan."

"You must have made some mistake," said I, with just enough acerbity in my tone to further excite the critical faculty in my son. I suppose the early growth of the critical faculty in sons should be respected, for it is a mark of the growing power of the coming man. It keeps the self-respecting parent on the guard against making errors.

"I have measured the distance repeatedly," replied Philip, "and it does not agree with the distance measured on our map. I have been thinking the matter over, and I believe all the books and methods are way out. Suppose there was a mountain a mile high on our land just between the two corners of our field. If we measured over the mountain the distance between the two corners we should find it more than two miles instead of five hundred feet as it is represented on our map."

"Oh," said I, a light dawning in my slow mind, "there is a deep gully or valley in that part of the field you refer to and you measured down and up the slopes of the ravine."

"Certainly," said Philip.

"If there had been a hole in the earth way to the centre just there, would you measure down to the centre of the earth and then up again?"

"I should think not," replied Philip with a courteous laugh which was just on the line of discourtesy. "I would measure across the hole."

"I don't see, then, why one should measure up to the top of a mountain, and then down on the other side," said I. "We made a plan of the land just as it would appear if you looked down upon it from a balloon."

Philip began to look a little foolish. "What we want is a straight level line across the ravine," said he, at length. "I don't see that we got that point out of George Washington's survey; I think he must have made some big mistakes if he measured up and down the mountains of Virginia."

"He probably held the surveyor's chain level between the points he stretched it," said I. "Suppose we try this method over the ravine to-morrow?"

Philip was ready to give in, as he expressed it; but I wanted to have the pleasure of satisfying my own mind of the justness of my conclusions, and perhaps there was a little malicious sense in showing Philip that his father was still a trifle in advance of him—not much,I confessed to my inward self.

Well, the following day we took a tape and our stick which was measured off in feet, and we measured across the field from one corner to the opposite one, holding the tape as nearly horizontal as possible when we made our way across the valley or ravine. I called Philip's attention to the fact that between distances of fifty feet the fall of level crossing the ravine was much greater than anywhere else on the line between the two corners, and that if we should draw lines between the points where the fall of level was the same, these lines would come nearer together in the ravine; they would seem to crowd through it, if we could look down upon them from a balloon.

The idea occurred to me to suggest to Philip to cut a potato into slices of equal thickness, and then having built up the potato again, to look down upon it as one would look down on a hill around which one had marked out lines of equal level or contour lines. Having done so, we both saw immediately that where these lines of level were near together, there was the steepest slope of the potato. If we could slice our golf field just as we sliced the potato (Fig. 6), and then look down upon it, we should be able at a glance to tell where the steep slopes were, and where the level places. I confess I found the determination of these lines of level a very engrossing pursuit.

I said a moment ago that all thinkers have their moments of elation, and in turn their moods of depression. Philip's schoolmaster came out of town one afternoon to see our field operations, of which he had learned something from Philip. He pointed out that after Philip had had a systematic training in geometry and trigonometry, he would have little difficulty with the problems which arise in surveying. He also said that the plane table should have a telescope instead of our rude sights, and he described various accurate instruments, and intimated that I was cultivating habits of inaccuracy in Philip. Training in science which was not highly accurate, he believed was worse than no training at all. I listened, but I remembered that this teacher had kept Philip at work making highly accurate measurements with a delicate balance. The boy had not appreciated the construction of the balance, for he had never made weighings with a rough instrument, and his mind had been kept so fixed upon the third place of decimals, that he did not appreciate what specific gravity really means.

I could see that the schoolmaster, in his endeavour to refine, had forgotten the difficulties of an immature mind. Philip was on one contour line and he on another, and it would take more than a megaphone to put them into communication; whereas I was studying with the boy, and only a little ahead of him. The schoolmaster put me on the defensive, which is not a cheerful mental attitude. I encountered, however, a more unpleasant critic in my new neighbour Stifton—the father of the boy with the baseball bat in spring, and the football costume in the autumn. Stifton played golf with me, and often called in the evenings. He was a rich man, who had made his money somewhat suddenly, after a lifetime devoted closely to business. Having retired from active affairs, he was seeking enjoyment in life after he had lost the faculty of enjoyment. What can be more mournful? Yet Stifton did not seem at all mournful, and sought to point out to me the futility of my work.

"I saw you working over your golf grounds," said he, one evening as we sat smoking in the study after dinner. "Laying out more links?"

"Philip and I are surveying the grounds," I replied.

"Surveying!" he ejaculated. "Why don't you get a surveyor to do it for you?"

"I enjoy the work," said I, "and Philip is learning to survey. By the way, how is your boy doing in college? What is he studying?"

"Billy was home last night," he replied, "and I inquired into his college studies. He said he was taking chemistry. 'What are you doing that for?' said I. 'You can pay a German to do all your chemistry for you.' Well, he said he was studying electricity. 'There again,' said I, 'every technical school in the country is turning out electricians by the score. You are going to have plenty of money, and if you desire to embark in electrical enterprises you can hire a fellow for fifteen hundred or two thousand dollars to do your electricity for you.' "

"Money," said I, with a reflective manner, "is a great power; one can even pay a man to play our part in life."

"'What you want to do, Billy,'" continued my neighbour, who had not heard my remark, so intent was he in giving me an idea of his wisdom—'what you want to do is to know men, to study subjects which will enable you to understand and control men.' Good heavens, Richard, think of our legislators and the muddle they make for us! If they would only study finance a little, or the laws of supply and demand, instead of striving merely to control and influence men."

My neighbour has entirely neglected his boys, having hired teachers to attend to their education. This he conceives of as an exhibition of the executive faculty. His boy Billy came home lately from college, and my wife and I were invited to dinner to meet him. He regaled us during the entire meal on the comparative merits of the full back and the quarter back of his college team compared with their opponents on a rival team. When I broached a literary topic there was an awkward silence at the table. I felt that I had been talked over in a family conclave before the event, and that I had fulfilled a knowing presage. The conversation immediately drifted back to the athletic question. The young collegian is a good fellow, and might have been interested in serious matters. Once he asked his father a business question, but the latter did not deign to answer. The father proposes to leave his boy a large fortune, and he has made no effort to build up a character. Has he not shifted a responsibility?

I am studying my neighbour, as you perceive. We play golf together, and occasionally billiards. He is intensely interested in winning, and I believe that the beautiful day and the budding springtime make no more impression upon him than I suppose that the sunlit fairylike depths of the sea at Bermuda make upon the shark intent on its prey.

VIII.

I HAVE spoken of my neighbour Stifton with the practical views of life. I have still another neighbour with what the world calls ideal views. Ruysart is a sculptor who has a commission to execute a statue representing Honour for the State Capitol. He has been engaged many years in perfecting his designs, for his ideal is so high that no amount of labour and pains seem to him too great to endeavour to attain it. He has a beautiful boy whom one sees tumbling about the father's studio. I have been greatly interested in watching the child. He evidently looks with a certain awe and veneration upon his father's work, for I have seen him cease from his more or less noisy play and look at the statue with the greatest interest, and sometimes he would ask questions in regard to it, which, however, received no answers from the absorbed artist. Then the boy would turn away and begin his racket to such a degree that the father would drive him out of the studio.

Once I suggested that it would be well to cultivate the interest of the boy for something besides mere play.

"Children are little animals," replied the sculptor. "Let them play and gambol. In time he will show the bent of his mind, and then I can decide how to bring him up and whether to make a blacksmith of him or an artist. Rabelais said that a boy should not be set to learning before his twelfth year; let him cultivate his body until then."

"I do not refer to the mere acquirement of learning," said I, "but rather to the acquisition of habits of industry and inquiry. I see in your little boy's face an almost pathetic desire to be included in your interests. Why not teach him insensibly by requiring some little daily task—some little exercise in drawing and modelling?"

Ruysart gazed at me with a dumfounded look.

"With my life's work, have I time to turn schoolmaster?" he asked. "An artist can not devote an hour to this drudgery and an hour to that drudgery; he can not parcel out his time like a business man or an executive officer, and hope to realize his artistic ideals."

"You want your boy to be an honour to the State as well as your statue?" I remarked.

"Oh, Francis will come all right in time," laughed the sculptor. "I was allowed to run wild up to my twentieth year, and then I found my vocation."

"A strong predisposition for a certain career often saves a boy from being wrecked," said I. "It may act like a Gulf Stream in the ocean, in carrying a ship which is not carefully manned and navigated to some port. There are many chances, however, of wreckage, unless one provides safeguards and exercises knowledge and gains experience."

I saw a look of annoyance come over Ruysart's face as I spoke, and he demolished his clay model and began to build it up anew. He evidently regarded me as a man with a fad, and having momentarily failed in realizing his ideal statue, he was ready in his impatience to uproot my educational structure.

"The world is now filled," he exclaimed, "with sentimentalists in education, all of whom have their patent methods. The poor unfortunate plant is so trimmed and cut and overfertilized that it loses the character and natural grace which God gave it. A rose is made as large as a cabbage—a perfect monstrosity. O for a lodge in a forest dell, where the wild rose blooms with its five perfect petals and where the bird sings its native note! The plant and the bird and the child must have freedom to develop their natural attributes."

"We must remember," I rejoined, "that the surroundings of children have been made more or less artificial for hundreds of years, and that we have to guard against certain evils, such as bad associates. Moreover, children are not passive, like plants.

The sculptor relapsed into a brooding study of clay which he was striving to form, and I left him. In passing out of his working rooms I saw a beautifully finished statue of a boy which was protected from dust and soiling fingers by means of a glass case. Outside the studio I saw the sculptor's boy playing with a number of unkempt children.

You have wondered how I met the athletic question in my scheme of a parent's responsibility. I confess that this question gave Philip's mother and myself much concern. My neighbour Stifton said: "Your boy will be deserted by his kind if you do not let him enter into the fierce competition of athletic contests. Moreover, if your boy's physical system is not constantly exercised, he will seek excitement in undesirable ways. '*Mens sana in corpore sano*,' you know. Let him loose in these boyish encounters; he will get his corners rubbed off and will learn mankind through boy kind."

I was forced to confess that there was considerable truth in these remarks. It would not do to antagonize the boy, and I did my best to inculcate the truth that mere muscular strength and capability of strenuous exertion for comparatively short intervals of time did not necessarily fit a man for the struggle of life.

I remember well a discussion between Philip and Professor Scribain one night as he sat before an open fire in my study. Philip had caught the fever of athletic competition, and was somewhat restive under my advice to cultivate endurance rather than muscular strength. The professor listened to our animated discussion, gazing into the embers. You remember the professor? He has grown thinner even than when we were in college, and as he sat in "lean and slippered pantaloon," one leg crossing the other, made a spiral which he kept from unwinding by the toe of his foot. You also remember the little derisive snorts he indulged in? These, occurring at intervals, spurred Philip on to make the assertion that the men of action and influence in the future were to be athletic men. This assertion roused the professor.

"Plato remarks," said he, "that the famous athletes, of whom the world has lost even the names, did not distinguish themselves in the army or the councils of state. It is evident, however, that Plato had a due sense of the importance of athletics, for Montaigne says:

"'It is admirable to see how solicitous Plato is in his laws for the gaiety and diversion of the youth of his city, and how he enlarges upon their races, sports, songs, leaps, and dances, of which he says that antiquity has given the ordering and patronage to the gods themselves—to Apollo, Minerva, and the Muses. He insists upon a thousand precepts for exercise; but as to the lettered sciences says very little, and only seems particularly to recommend poetry upon the account of music.'

"But Plato valued athletics only as a means of all-round development, and we may well ask, with him, Have the athletes made their mark in the book of time?

"Were Alexander Pope or the elder or younger Pitt athletes? Did we ever hear of Washington or Lincoln or Grant using chest weights? Where are the strong men of my class in college? There was Smith, with arms like a blacksmith; he could lift two hundred-pound dumbbells above his head, one in each hand. Where is Smith?—dead. Where is Brown, the great oar, with back like Atlas and legs with muscles like iron? Where is Brown?—dead. Where is Tyler, the man who ran like a deer, who held the world's record for a one hundred yards dash? Where is he?—dead. And I, the feeblest man in the class—I, who weighed one hundred pounds on my graduation day—I—I still live.

"Your father is right, Philip. Heads, and not legs, are the controlling factors in the progress of humanity. You need endurance, rather than strength, for the world's battle [snort]. If you were going to run races all your life, possibly you could accustom your heart to the tremendous strain you put upon it; but the duties of life intervene, and your abnormal movement of the heart does not resume a normal movement. No; take a dog and a gun and tramp over the hills and through the woods, and cultivate in God's air your powers of endurance. Tramp with the hare and the hounds if you are too tender-hearted to kill birds, ride with the hounds if you have no compassion for foxes, skate up the lonely rivers if you are a lover of Nature and solitude, cultivate in the open air your powers of nervous and physical endurance, and, when you indulge in games, go in for sport and love of the freedom of play rather than for fierce competition, which is the bane of our college sports. Why, in playing golf, for instance, can't you enjoy the breezy down, the wide canopy of heaven, without playing feverishly against your yesterday's score? When I was in college several of us took long tramps about the surrounding country. We did not try to outrun some other fellows [snort]; but we looked at the birds, at the sky and the trees. Nature appealed to our spirit, and we came back refreshed, and, sitting before our open fire forty years ago, we talked of the poets, we discussed our classic authors, we talked politics. What do you fellows do now? When you get together you discuss the merits of Smith as quarter back, you foot up athletic records. Do you ever talk of anything spiritual or intellectual?"

"My boy does," said Philip's mother, gently.

"Thanks to his parents," replied the professor. "They have not shifted their responsibility." He remained in a deeply reflective mood some time after his oration on athletics, which, I told Philip, might be termed *morituri salutamus.*

"I have been thinking," said he, at length, "of your neighbour Stifton's contention that athletics keeps a boy out of something worse. This is true to a certain extent; but excess in athletics is like all forms of dissipation, which are characterized by violent reactions. Moreover, when a student goes into actual life he can not find time to indulge in the violent exercises to which he has habituated himself, and accordingly the balance of his physical being is put out of good running order. It is better that he should get a love for enduring forms of physical exercise. Locke, whom I have often quoted, says: 'In the next this place the great horn-like peak soars into the blue sky from an extensive Alp or almost level pasture, its great glacier forming an icy wall full of emerald-green crevasses on the western horizon. Philip was using his finger, with a foot rule before his eye at such a distance that he covered the height of the great peak. I overheard him explain to the Englishman that, by knowing the distance he held the rule from his eye, and estimating the distance to the foot of the mountain, he could form an estimate of the height of the latter. For if he should draw a figure (Fig. 7), and lay off the distances *A C* and *B C* and *A D*, he could by drawing *A E* then draw *D E*.

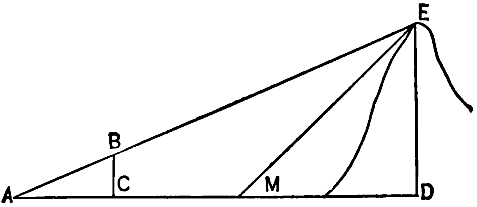

FIG. 7.

He also explained an instrument which he had thought out. It consisted simply of a board provided with two sights (Fig. 8), like a rifle barrel. At one end was placed a paper divided into degrees. A thread carrying a weight was suspended at the centre of the graduated arc. A slight touch of the finger on the string enabled one to steady it against the graduated arc. When the line of sights was fixed on the summit of the mountain, knowing the angle *A B C*, he could afterward measure the angle *C A B* by the same graduated circle, and this latter angle was the angular altitude of the distant object above the horizon line *A C*.

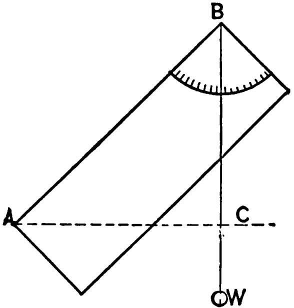

FIG. 8.

Mr. Balfour said our methods answered fairly well in the case of a mountain which rose so abruptly from the more or less level Alp; but a more accurate method would be to measure to the centre of the mountain.

"Do it, sir," said Philip, offering his foot rule.

Mr. Balfour burst into a fit of laughter, and said he had never had such a challenge before but once, and that was when he had been discussing the subject of dew with a young American lady, and she had asked him if a sieve could be made so fine that water would pass through it in the form of dew, and when he said he thought it might be possible, she replied, "Do it, sir."

Philip acknowledged that his estimate might be considerably in error, for the base of the mountain covered a large area, and he could only measure to the sloping wall of a great side of rock which was far from the centre of the base. Mr. Balfour suggested that Philip should pace off a distance of about a hundred feet and sight to the top of the mountain from the two ends of this distance, and then having represented the distance *A M* on paper (Fig. 7), and having drawn the inclination of the lines *A E* and *M E*, these lines would intersect at the top of the mountain *E*. Then he could drop a perpendicular line *E D* to meet the one-hundred-foot line produced to *D*, and *D E* would then be more accurately the height of the mountain. Philip immediately put this plan into execution, and obtained 6,200 feet for the elevation of the mountain above the place where we were sitting. The height of the Matterhorn above the sea is given by Baedecker as 14,705 feet, and the height of the Schwartz See 8,392. The difference of these heights is 5,313 feet, so that Philip was not so very far out of the way.

Mr. Balfour then explained his method of telegraphing to his friends who were toiling up the slopes of the mountain. We could see them through his eyeglass—four figures, two Englishmen and two guides—all connected by a rope. Every now and then the sun seemed to catch something bright in the party, and was reflected to us.

"They say," remarked Mr. Balfour, "that there has been a fresh fall of snow, and that it is slippery."

We wondered how he knew that they said this. Then we saw him take a little mirror, and looking through his telescope which he had mounted on his camera tripod, he reflected the sun up the side of the mountain, moving the mirror to and fro. We saw the gleam of light from the party on the peak come and go in response to his signals.

"They say that one of the party is unable to proceed farther," remarked Mr. Balfour, with an air of concern. We did not ask any questions in regard to his method of telegraphing with the mirror and the sun, but waited until he had relieved his anxiety by watching the acts of the mountaineers.

"Now they have turned and are descending," he said, taking his eyes from the telescope. "The guides are sensible fellows, and they don't like the looks of those clouds that are gathering. The principal peril on that mountain is from the weather." Having satisfied his mind in regard to the actions of his friends, he explained his method of signalling, which consisted simply in reflecting the sun on the moving party and making intervals between the flashes, according to a preconcerted system of signals which was very similar to the system used in electric telegraphy.

The Englishman, having explained his experiments, evidently thought it would be courteous to refer to Philip's attempt to determine the height of the Matterhorn.

"Did you know," said he, turning to me, "that you and Philip have rediscovered the principle of two instruments the invention of which date from great antiquity—the quadrant and the astrolabe? When we return to the hotel tonight I will read you some extracts from a treatise on the astrolabe by Chaucer. It is interesting that an imaginative poet should have written a treatise on a scientific instrument for the use of his son. Chaucer evidently felt the responsibility of a father, as you do. His was not the case, however, of a commonplace father and a bright son, as you would fain make me believe is your case."

Accordingly, after dinner, when we rested from our excursions, the Englishman produced Chaucer's treatise.

"It begins as follows," said he:

"'Lytel Lowys my Sone, I perceyve wel by certeyn evydences thyn abylite to lerne sciences touchinge nombres and proporcions and also wel consydre I thy besye prayer in special to lerne the tretys of the Astrolabie.'

"Isn't the old English quaint?" asked Balfour, pausing in his reading. "By the way, the 'Lytel Sone' must have been brighter than boys are nowadays, for he was apparently only ten years of age. It is true that the poet proposes to treat his son with consideration, for he says that some points in regard to the use of the instrument 'ben too harde to thy tender age of ten yere to conceyve.'

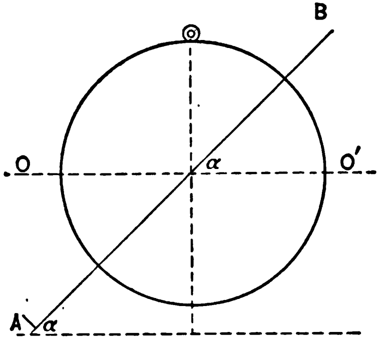

FIG. 9.

"The astrolabe, in its simplest form, consists merely of a circle graduated in degrees. It is suspended from a ring, and a *rewle* or index arm, *A B* (Fig. 9), moves about the centre of the graduated circle. This index arm has two sight holes, one at *A* and the other at *B*. By sighting through these holes at the top of a mountain one can get its altitude, above the horizon or level line, *O O′*, in degrees.

"You will find in Lane's Arabian Nights the following description of an astrolabe:

"'The astrolabe is more commonly used by the Arabs than any other instrument for astronomical observations. It is generally between four and six inches in diameter. It consists of a circular plate with a graduated rim, within which fit several thinner plates, and of a limb, moving on a pivot in the centre, with two sights. The plates are engraved with complicated diagrams, etc., for various calculations. The instrument is held by a ring, or by a loop of cord attached to the ring, during an observation, and thus its own weight answers the same purpose as the plumb-line of the quadrant (which the Arabs sometimes use in its stead), the position of the movable limb, with the sights, marking the required altitude.'

"See how Chaucer instructs his son to use the instrument in obtaining the height of the sun above the sea level:

"'To knowe the altitude of the Sonne, eythcr of celestiale bodies.

"'Sette the ring of thyne astrolabie upon thy ryghte thombe and tourne thy lyfte syde again the light of the Sonne and remeve thy rewle up and down till the streme of the Sonne shyne through both holes of the rewle; loke then how many degrees this rewle is areised fro the littel crosse upon the Est lyne, and take there the altitude of thy Sonne. And in this same wise maiest thou knowe by nighte the altitude of the Mone or of the brighte Sterres.

"'This chapter is so general ever in one that there nedeth no more declaracion; but forget it not.'"

I had many conversations with this Englishman on the subject of the education of boys, and I found that he did not believe with Locke that a boy should be kept from great public schools, and should be under a tutor. "Look at the records of Eton and Harrow and Rugby," said he, "and see what a number of distinguished men have come from them—men who have not lost their virtue in their rough schooling. Did you ever read the amusing letters between young Hare and Henry Temple, the future Lord Palmerston? I have just found them in Bulwer's Life of Palmerston. I will read you a portion of them. The boys were fourteen years of age. Francis George Hare writes thus:

BOLOGNA, *January 5, 1798.*

I hope, dear Harry, that you continue always well, and that you profit much at school, both in Greek and Latin. I make you this wish, as I think it the very best that a true friend can make, and I think I ought to believe that you place me in this number.

I hope that you take no part in those vices which are common to a public school, such as I suppose Harrow is, swearing and getting drunk. But I imagine the son of a gentleman so well taught can not partake in things like these. Pray give a kiss to each of your two amiable sisters, but particularly to Fanny, and tell her to write me a letter whenever you answer mine. I still persist in my opinion of never marrying, and I suppose you think the same, as you must have read as well as myself of the many faults and vices of women. Perhaps I, at Bologna, may have learnt more Greek than you, and that you at Harrow may know best how to fight with your fist. However, if you challenge me, I shall not hesitate to accept, for I remember I am an English boy, and will behave like a brave one.

"To this Henry Temple thus responds:

I am sincerely obliged to you for your kind wish, and trust that I make as much progress as boys in my situation at school generally do. I have begun Homer's Iliad, which I did in that beautiful episode, in the sixth book, I think, in which Andromache takes leave of Hector, when returning from the war to Troy, to order a general supplication to Minerva. . . .

I am now doing Cæsar, Terence, Ovid, Homer, Greek Testament, and a collection of Greek epigrams, and after the Easter holidays, which are now drawing near, I shall begin Virgil, Horace, and

> some more. I am perfectly of your opinion concerning drinking and swearing, which, though fashionable at present, I think extremely ungentlemanlike; as for getting drunk, I can find no pleasure in it. . . .
>
> I can not agree with you about marriage, though I should be by no means precipitate about my choice.

"Now, in the States, could you find two boys at school who write thus about their studies?"

We found Mr. Balfour a very interesting man, and Philip laid the foundation of a friendship which was destined to influence his career, for the Englishman afterward became one of the Queen's judges, and was of great assistance, you will remember, to Philip, when the latter was intrusted by the Government with the negotiation of the Brien affair.

By the way, you have now heard doubtless of the sad story of Reginald Ruysart. His father, it is said, is totally incapacitated for work, so much is he affected by his son's fate.

You know that Ruysart was given a commission some ten years ago to execute a statue of Honour for a niche in our city library. Well, you are aware of his extreme conscientiousness in his art. He has worked away at this commission, making models innumerable, and studying the subject from every possible aspect. I used to visit his studio often, and I have told you how on these visits I frequently saw his curly-headed boy come in and ask his father a question. He was always shown the door with an air of annoyance. I was pained at this conduct, for I caught a look on the boy's face which spoke volumes to me, and I gently remonstrated with the father, but it was of no use; boys were troublesome creatures, and should be kept at school. I entered a little into my theory of home education, but I soon saw it was of no use. He hadn't time, and he worked away at his statue of Honour, striving to express in cold marble a sentiment which he hoped would influence the coming generations which should gaze at it. Meanwhile he had at hand a creature of flesh and blood, not a bit of cold stone, which he could so shape and influence that the man might be a shining example way down the ages yet to come, and might lead the world to righteousness. That boy is now in the State's prison, and the father is still at work on his statue of Honour.

Professor Scribain informed me of this sad news, and after reflecting on the strange selfishness of mankind closed his account of the matter as follows: "As Montaigne says, 'Nay, I make great question whether Phidias, or any other excellent statuary, would be so solicitous of the preservation and continuance of his natural children as he would be of a rare statue which, with long labour and study he had perfected according to art.'"

X.

During the evenings at Zermatt we met many interesting people. Among them was an American photographer, who was a constant source of amusement to Mr. Balfour. His name was Lanthamum, and the Englishman generally referred to him as Brother Jonathamum. The photographer was employed by a lecturer to collect views in the Alps, and he was full of interesting bits of information both in regard to the walks which he took and the arts which he practised. He took Philip and myself into his room at night and showed us how he developed his pictures. He explained that he kept most of his views for development after he should return to America. Occasionally, however, he was anxious to ascertain whether he had been successful in obtaining a difficult view, and he proceeded to develop. I had always supposed that a dark room filled with elaborate contrivances was necessary to cultivate the art of photography; but I find that much can be done with very simple means. The photographer put his candle on the floor in a corner of the room, behind an opened umbrella. Over the umbrella was spread a sheet of brown wrapping paper. A similar sheet of brown paper served to reflect the light of the candle, away from the corner where he worked with his developing trays. He explained that his greatest difficulty was in obtaining sufficient water to wash the plates after they had been developed and fixed. "A man who is determined upon accomplishing a result," he remarked, holding one of his pictures critically up to the light, "can generally do it if he works long enough, and if the Lord has been fairly generous to him. The trouble is generally with the man or his parents."

One evening he related the following story of an early experience in photography, which illustrated the character of the man:

John Lanthamum, after graduating from a high school, entered into the employment of a Mr. Smiles, who was preparing a course of lectures on the scenery of the American Switzerland, which was to be profusely illustrated—to use the language of Mr. Smiles's circular—by stereopticon views. John journeyed with the lecturer to Alaska and made many ascents of difficult peaks in order to obtain the most impressive pictures.

"We have now all I desire," said Mr. Smiles one day to John, "with the exception of a photograph of 'the Snow Finger'; and I greatly desire one of that marvellous object."

John felt that it would be very difficult to obtain the desired picture; for a long and perilous ascent must be made of a snow mountain, in order to reach a point from which the Snow Finger could be seen in all its weird and savage grandeur. The guides in that region said that the effect of the great finger pointing to heaven in the morning or evening light was indescribable.

"I can feel a thrill run through my audience," remarked Mr. Smiles, "when I project an image of the Snow Finger on the screen."

The lecturer was an enthusiastic man, and Lanthamum was an ardent photographer. It seemed that, if enthusiasm is a great moving force in the world, it ought to overcome the difficulties in obtaining a picture of this marvellous natural object. He immediately engaged the best guides the country afforded, and made a careful preparation for the undertaking.

Mr. Smiles was told that the best photographs of distant mountain peaks could be taken with a long-focus lens; for in the ordinary camera mountains lose their grandeur and the near objects are made too prominent.

"A long-focus lens acts like time in bringing out the grandeur of a great character, and sinks the too obtrusive present," said Mr. Smiles, thinking how well this would sound in his lecture. "We must have a long-focus lens by all means."

Lanthamum therefore sent to San Francisco for a suitable lens and a larger camera. It was delightful to work for Mr. Smiles, for he was an enthusiast.

When the new lens and the camera arrived, all the necessary preparations had been made for the journey over the snow fields and glaciers to the point from which the Snow Finger could be photographed. The new camera was strapped upon the back of one guide; Lanthamum carried the precious lens and the sensitive plates, while to a second guide was intrusted the necessary provisions.

Mountaineering in British America and Alaska has not reached that perfection to which it has attained in Switzerland. It is difficult to obtain competent guides, and the paths are not well known. John insisted that a rope should be tied to the waists of the guides and to himself, for there were doubtless crevasses beneath the coating of snow. The guides demurred at first, for they were American citizens, and the rope seemed a badge of slavery. One of them, however, soon disappeared, or "slumped," as he afterward said, into a deep crevasse, and was pulled out by means of the rope; thereafter both guides tramped on, content to learn something from an older country. The way over the lower range of mountains was long and arduous, and the party descended a great slope, in order to cross the glacier which extended up and through the passes of the snow mountains, like the blue-veined giant hand of age holding beautiful statues of snowy whiteness. It was hard to sacrifice the height which had been attained by hours of strenuous effort, and to descend again only to be compelled to toil upward when the glacier was crossed. Philip remembered how often in the practice of the art of photography he had been compelled to take to pieces apparatus which he had built up with infinite pains, in order to reach greater excellence; and he descended with a steady heart. The guides, however, grumbled much, and the one who carried the large camera complained of its cumbrousness. He evidently thought that Lanthamum was a clumsy photographer.

"One of my folks," said he, "had a camera about the size of my hand which took beautiful pictures. I'd a got one like it if I'd known we were going on this trip."

"It wouldn't answer for obtaining a picture of the Snow Finger," said Lanthamum courteously.

"It was a wonderful camera," continued the guide. "It took a fine likeness of the mayor of our town, and I guess it was equal to taking a picture of the Snow Finger, and you could carry it in your pocket."

The guides shook their heads and grumbled; but the sturdy young photographer was their master and he bore down all criticism.

On and on they toiled, now along the steep side of a mountain, picking their footsteps in the great rocky seams; now down again upon a branch of the glacier over its winding surface. While crossing the last branch of the glacier the photographer fell, and the long-focus lens which he was carrying with the greatest care rolled into a deep crevasse. It was a dreadful moment. Lanthamum gazed into the dark opening, and had a mind to explore its mysterious depths. Without the lens their walking for the past five hours promised to be of no avail. The half-hearted guides were now sure that they were bound on an unsuccessful venture, under the leadership of a boy who did not understand his business.

"Guess we'd better make tracks for home now," grumbled Mathews, the elder guide.

"We've lost the muzzle of our gun," said Thomas, his companion.

"How far is it to the cabin where we were to spend the night?" asked Lanthamum.

"It's a good hour's walk yet," replied Mathews, who, in company with Thomas, was already moving toward home.

"We will spend the night in the cabin," said Lanthamum calmly, "and we will take a photograph in the morning."

"How can you take a photograph without a lens?" asked Mathews.

"I shall make an ice lens," replied the photographer.

The two guides looked at each other with astonishment depicted on their countenances, and with the innate desire of Americans to see something new in the way of invention, they resumed their march to the cabin. The rude shelter in which Philip proposed to pass the night was a species of cave under a sheer mountain wall. This wall formed nearly two sides of the cabin, and some enthusiastic mountaineers who had brought down reports of the marvellous beauty of the Snow Finger had inclosed the cabin by building an outer wall. They had also left some skins and blankets in the retreat.

While the guides slept about the fire, Lanthamum busied himself with his photographic apparatus. He cut out of the ice formation near the cabin a piece of pure ice and shaped it into the form of a convex lens. There was no trouble in finding a perfectly translucent piece of ice; but the difficulty in obtaining a good image of the full moon, which had now risen over the great Snow Finger, and which the white finger pointed at as something purer and more chaste even than itself, was greater than he had imagined. The lens threw a blurred image—an image which was not sharply rounded—on the wall of the mountain. The night was icy cold, and the stars shone their brightest. A brilliant planet rose behind the forefinger. It was a diamond on a ring which was being presented by Endymion to the moon.

The ice lens would not melt in the cold air. John took it into the cabin and touched it here and there with his warm finger in order to fashion its surfaces, so that it might give a better image. Never before had he realized the truth of a remark of an old optician who once told him that it required an artist in his trade to make a good lens. The slightest unevenness or fault in curvature is sufficient to distort a beautiful object into a hideous caricature. "Remember," said the old optician to his listener, "that your character resembles a lens: if it is well formed it will give a beautiful image of the world in which you are placed. If it is badly shaped it will turn even beauty itself into a hideous object."

Lanthamum worked assiduously half the night. A mere touch on the lens would often destroy the previous work. Through all the hours which he spent in strenuous endeavour after perfection the guides slept heavily. Lanthamum felt a strange elation of spirits as he looked at the brilliant constellation overhead, and heard the snoring of the men in the cabin; and his striving to conquer obstacles and to attain perfection seemed to lift him into a higher world than that in which his companions slept and dreamed like dogs.

"If I can not succeed in making a good ice lens," said he to himself, "I can at least photograph the great Snow Finger through a pin hole." If the guides had heard him say this they would undoubtedly have arisen, and with growls of contempt set out for home, with the determination to have nothing more to do with a madman.

The photographer fitted a thin black disk to the opening of his camera where the lens had been, and made a small pin hole in the centre of the disk.

"I am sure," said he, "of getting a picture of the Snow Finger by means of this pin hole. In order, however, to get a good one to cover a sensitive plate, which is eight inches wide by ten inches long—the size I hoped to take with the lens which fell into the crevasse—I ought to have a camera box at least seven feet in length." He pondered long over the problem, while the flames from the fire threw grotesque shadow images of himself like a huge necromancer keeping watch over the sleeping animals.

The seven-feet-long camera must be a dark one, and it seemed to be impossible to obtain it. The study of science, however, cultivates infinite patience and perseverance. Lanthamum surveyed the mountain wall outside the cabin. Beyond the cabin snowdrifts were piled at its foot.

"If I could tunnel through that snowdrift, which lies like a great flying arch," said he, "and place my camera at one end of the tunnel and a pin hole at the other, I could obtain what I desire. The difficulty would be in preventing diffuse light inside such a camera tunnel." The stars twinkled and seemed to nod their approval of his high and indomitable perseverance—as if willing to receive him into their company. He turned from a long contemplation of the snowdrift, and with a definite plan in his head went to sleep.

The morning sun rose resplendent over the great range of snow peaks. The photographer, after a few more finishing touches, put his ice lens into position and took a view of the Snow Finger.

"I do not expect a good photograph," he thought to himself, "but I must take a picture to keep my influence with the guides, who evidently expect much from such a simple idea." After several exposures were made with the ice lens, he put the pin hole in position and pointed the camera at the Snow Finger. He tried to explain to the guides that the use of a pin hole was similar to that of a very small diaphragm in an ordinary camera. "There is little use in having a lens if you use a very small diaphragm," he said in conclusion. His words, however, produced but little impression upon his audience. When he proposed that a tunnel should be excavated through the snowdrift, they were ready to vote him stark mad. It was useless to tell them that Lord Rayleigh, a distinguished Englishman, had taken fine pictures—equal to those taken by lenses—by means of a pin hole and a camera seven to nine feet long. They were Americans, and their idea of lords was gained from the funny papers. They fully believed that the man had been deluded, and they wondered why they had suffered themselves to be led so long by one who could be fooled so easily.

"I am going home," said Mathews with a growl.

"So be I," said Thomas, and both men started down the mountain side. They evidently expected that Lanthamum would follow and entreat them to return and take their share of the burdens. He, however, let them go, and turning to the snowdrift began to tunnel through it. He soon perceived that the principal difficulty in shutting out stray light would be at the two ends of the tunnel. It was necessary to put the blankets on the snow at the ends of the tunnel and to pile snow upon the blankets. When the tunnel was completed and he had exposed a plate, he saw the guides returning, with the evident intention of carrying him away bodily, as they might a madman. The photographer coolly pushed in the slide of his camera and said, "I have taken the pictures, and now I am ready to accompany you."

"He has come to his senses," said Mathews in a whisper to Thomas. They were in the full sunlight, and felt that they saw all that was possible to see. The stars, however, were twinkling and nodding to the photographer behind the glare of the sunlight; and he felt the same elation of spirit which came over him as he gazed at the constellations at midnight. He had been steadfast and had conquered the weaknesses of a mortal by infinite patience and perseverance. "*Ad astra per aspera*" was the motto which had been given him by his friend the old optician, as one well suited to be adopted by a photographer.

When Mr. Smiles threw a picture of the great Snow Finger on the screen by means of his stereopticon, he told how the photograph had been obtained, and the audience were greatly interested in the pictures taken with the ice lens. It seemed appropriate that the great Snow Finger should be pictured by a piece of its own substance. It must be acknowledged, however, that the views taken through a pin hole were much finer. The audience applauded the energy and perseverance shown by the young photographer; but Lanthamum had learned that there is a pleasure in triumphing over obstacles in the pursuit of science which is not dependent upon the applause of the world.

On the night when he had thought out his plans he seemed to have received inspiration from the stars. Men might applaud or not—there was a pure gratification in overcoming obstacles in the study of science.

XI.

Mr. Balfour was much interested in the glaciers, and Philip and I, equipped with ice axes and provided with a rope, often accompanied him on excursions in the neighbourhood of Zermatt. There is a peculiar pleasure in exploring a glacier. One can obtain all the excitement of an Alpine climb in surmounting the hummocks and crossing the crevasses of the ice without the danger which is imminent in climbing the steep crags and passing over the edges of great precipices of the aiguilles. Mr. Balfour's interest in the glaciers, however, was not alone in their affording opportunities for physical exercise. He was interested to discover how fast they moved down their beds, and why they moved. He had a faculty for making simple experiments which set one to thinking. In order to illustrate to Philip the effect of pressure in melting ice, he cut out a block of the latter from a crevasse, where it was fairly transparent, and having mounted it upon a pile of rocks on the moraine at the side of the glacier, he hung a wire with rocks tied to each end on the block, and told us that on our return from the excursion up the glacier we should find that the wire had cut through the block of ice, while its path had been frozen behind it as it proceeded. "The ice will melt under the wire by pressure," said he. "This operation I suppose also goes on at the bed of the glacier, for the weight of the ice must be enormous."

On our walk he stopped at a narrow crevasse and pulled up a rope which ran into it. At the end of the rope was a piece of a gas pipe, about two feet long, closed at one end. "I filled," said he, "this pipe with water to within a foot of the top. I wished to see how much the water would expand when it became ice."

"Doesn't the expansion of water when it becomes ice force the glacier down the mountain?" asked Philip.

"I suppose," said Mr. Balfour reflectively, "that this force of expansion is one of the forces which acts in the movement of these enormous masses. The great giant, the glacier, stretches his arms and yawns, and something has to give way."

The Englishman said he found that it added to the interest of a summer vacation in the Alps to have a fad, and the study of ice was his fad that summer. At one point on the glacier he was studying the rate at which it moved down the mountain, and to determine this rate he had placed across the glacier a number of stakes which were originally placed in line with two stakes fixed on the rock on the opposite sides of the glacier. By sighting across from one stake to the other he could determine if the intermediate stakes moved out of line. He had a number of such lines of stakes at places on the glacier where it was fed from different mountains, and he was endeavouring to ascertain how much the source of supply of snow affected the movement of the river of ice. He had an interesting way of regarding ice as a metal.

"Ice would make a better bridge than lead or tin," he remarked.

The struggles of Brother Jonathamum to get a good photograph of the Matterhorn interested the Englishman greatly, and Philip too participated in this interest. I confess I was glad to find a coadjutor in Mr. Balfour, and I took the opportunity while the photographic party were intent upon their work to make solitary excursions in quest of the Edelweiss.

It seems that Mr. Lanthamum was disappointed in the result produced by his landscape lens. The soaring height of the Matterhorn was not well reproduced, and he had therefore resolved to use a very long-focus lens, which, after many days of waiting, he had received at last from a German optician. It was not accompanied, however, by a long camera box, and he was therefore compelled to make such a box himself, with the aid of a carpenter in the village. I overheard him explain to Philip and Mr. Balfour the advantages of a long-focus lens for giving the height of distant objects in a proper proportion. He took his short-focus lens and threw an image of the sun on a piece of paper; the image of the sun was hardly more than a large-sized pinhead, while the image of the sun with the long-focus lens was as large as a ten-cent piece. He pointed out that the rays of light coming from distant objects were refracted more sharply in the case of the short-focus lens than in the case of the long-focus lens.

It was an amusing sight to see the photographic party set out. The mule which carried the long camera was almost hidden from view by it, and the mishaps that befell the camera were innumerable. Mr. Balfour always came home in a state of great hilarity, filled with American jokes. He maintained, that several times the peasants knelt as the mule passed and crossed themselves—mistaking the camera for a coffin. Brother Jonathamum, he remarked, had great doubts of their prayers reaching heaven on account of the distance between the nouns and verbs in the German language. The point of view selected by the photographer was that described by Ruskin in his Modern Painters; and the results given by the long-focus lens were certainly far better than those obtained with the ordinary camera lens. The good results which were obtained were doubtless also due in a measure to the device which Mr. Lanthamum used to increase the sensitiveness of his photographic plates for the yellow and green rays of light. One rainy evening he gave us a talk on the subject of the photography of colour. Although it is not possible yet to obtain the colours of Nature, it seems that a great advance has been made in representing the relative intensity of colours. For instance, it is now possible to photograph the shades in a yellow or green extent of pasture or Alp, whereas formerly such shades were obliterated by a common lack of detail. A blue dress on a peasant would be represented by the old photographic plates as a white dress without shadows or shades, but on the new, so-called orthochromatic plates all the folds and shades of the dress would be properly reproduced.

XII.

While we were at Zermatt the operation of building the railway to the Riffel was going on. At noon there was always a great sound of blasting. Philip and I amused ourselves by estimating the distance from the hotel in Zermatt to the point on the Riffel where the blasting took place. With watches in hand we noted the interval between the appearance of a puff of smoke and the sound of the explosion. Since sound travels at the rate of about a thousand feet per second, we could ascertain the distance if we estimated the interval of time correctly. Mr. Balfour joined us and also took the time with his watch. The average of several determinations was five and a half seconds, and we therefore made the distance something more than a mile. I suggested to Philip that it would be interesting to compare the result with one which he might obtain by using Mr. Balfour's method with the triangles.

Philip and the latter set out with great interest to make the measure. They paced off a distance in the meadow behind the hotel, and estimated the angle of elevation of the Riffel from the two ends of this base line. They then drew the triangle in a note book, and measured the line *D E* (Fig. 10), having laid off *A M* as a line of five inches. Their results by the two methods did not agree perfectly, and Mr. Balfour suggested that the difference of temperature in the layers of air on the height and in the valley might be the cause of the non-agreement.

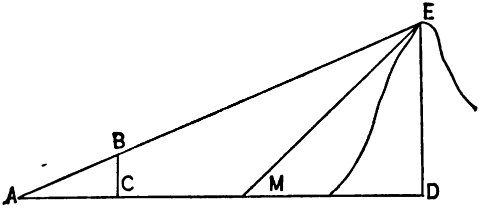

Fig. 10.

While we were at Zermatt we encountered my neighbour Stifton and his son. The latter was travelling with a tutor, who was endeavouring to teach him the German language by reading a portion of Wilhelm Tell each day. My neighbour was surprised to see Philip reading a German newspaper, and to hear him talking with the villagers and the Germans at the *table-d'hôte.* I do not pretend that he talked freely or grammatically; he got along fast, however, for he had a good vocabulary and a certain self-confidence. Stifton did the place with a growl; he had a large party of Americans with him—had hired all the best guides and mules in the place. Yet he did not seem to enjoy himself half as much as Mr. Lanthamum and Philip and the Englishman. Young Stifton too did not seem to have any interests, save in the arrival of Galignani's Messenger, and the only part of that sheet which he read was the record of sports. He has a little note book in which he kept a record of the highest running jumps.

It was amusing to see Stifton and our Englishman together. Stifton wondered why Balfour didn't pay some guides to make his measurements for him, and he questioned the use of the measurements. Altogether the American was a puzzle to the Englishman.

"If I hadn't met you and Brother Jonathamum," he ejaculated one day, "I should suppose that Americans had no fads except competition with their fellow-creatures. Strange too because I supposed that the American mind is essentially scientific rather than literary. I've long had a theory that science leads to optimism and interest in life, while literature tends to pessimism. If, however, you scientific and practical Americans have no fads, you exhibit in the person of Mr. Stifton a fearful pessimism."

"Do you think it is really true," I asked, "that scientific men, as a rule, are more optimistic than literary men?"

"I confess I've held that theory for some time," he replied.

"Literary men have had their Shakespeare, their Milton, and Goethe, who have well-nigh exhausted the resources of language. Human nature is depicted in the Bible also, and it has not changed materially for thousands of years. We shall always be able probably to summon a lot of rattle pates to war by beating on a pigskin. Science, however, has its treasures for us in the future. The scientific man looks forward and not backward. If I had a son, I would do as you are doing, awaken in him the scientific interest, give him an interest in life and all its operations." The Englishman grew eloquent as he promulgated his thesis. Presently his voice dropped. "I want to tell you," said he, after a short silence, "what the photographer, John Lanthamum, said while I was enunciating this doctrine as we sat on the Staffel Alp, and I watched his evident enjoyment in his work of getting a photograph of the Matterhorn:

"'It's all a question of temperryment,'" said he.

"There's philosophy in that," remarked Mr. Balfour. "If a boy, however, is taught to observe Nature, to draw, for without some knowledge of drawing, he can not observe keenly; to use his hands in some mechanical pursuit, in order to draw off through his fingers the tension on his brains, he can certainly overcome a pessimistic *temperryment* and perhaps be thankful for life."

I have remarked that one great advantage a father can give a boy, far superior to any money advantage, is the opportunity of mingling with the best people.

Philip's knack at sketching, I found, immediately made him friends among a delightful coterie of English people at the hotel of which Mr. Balfour constituted one. The fact is, the boy had interesting pursuits and a quick interest in life. I had great satisfaction in standing aside and seeing him entertain the company with his sketches of his tramp with the photographer, and hearing his enthusiastic account of the variety of flowers he saw on the Staffel Alp. There were at least twenty varieties of gentians and violets. To wander over the great pastures guarded by the tremendous wall of rock of the Matterhorn, and pick these flowers in the perfect quiet of the place, was an extraordinary sensation. Stifton and son had come over that Alp, and had found it a longer way than that by the Schwartz See, and deadly uninteresting.

One of the English ladies—Lady Templeton—became interested in Philip's drawings, and taught him how to sketch in water colours. The boy could not be made an artist. His mind was interested in a great variety of subjects, and had not an overwhelming tendency in one direction. If I had thrown him off, repulsed his curiosity, and compelled him to associate with any companion he might have met, what would have been his future?

I received yesterday a despairing letter from sculptor Ruysart. He blames society, the college, the times, and attributes the wreck of his son to the general degeneracy of city life.

What can I reply? It is too late to tell the truth.

There is one hopeful strain in his letter—he has finished his marble inanimate statue of Honour.

Philip and I were much interested in the use of water power in Switzerland, and we thought of utilizing the stream which runs through my woodland for lighting our home. The first exhibition we had of the use of water was at a spot near the Castle of Chillon. Here a car ascends a steep incline by a very simple device. There are two sets of rails with a car on each set. These cars are connected by a chain which passes over a pulley. One can lift the other by means of a suitable amount of water which flows into a tank in the car at the top of the incline and flows out when the descending car has reached the foot of the incline. The cars run, therefore, by the force of gravitation. It was interesting to note how quickly Philip understood the method of running the cars. This quick intelligence, I could not help believing, was the result of my interesting him from an early age in the phenomena about him.

Some of these water railroads in Switzerland are fearful; one feels that one is suspended in mid air over a precipice. The arrangement is a species of elevator running on an incline instead of in a vertical shaft.

We found many little villages lighted by electricity. How many ages the peasants had tramped over the bridges which spanned the water courses and never suspected the existence of a source of light and heat in the cold water!

During my journeys, my dear Richard, I was in a jubilant mood, for I had my reward for those early years of patient effort, through much discouragement, in teaching Philip. I had formed for myself an intelligent travelling companion. It was well worth the pains and labour I undertook.

XIII.

I found that on our outward voyage to Europe Philip was interested in seeing the officers obtain their latitude by means of the sextant, and my mind too ran on the methods of getting the ship's position at sea. I had a notion of how it was done, but the notion was very indefinite, and during the voyage I endeavoured to ascertain how the latitude and longitude were obtained. I hesitated to bother the officers of the ship; for I really had not much hope of obtaining information from them which I could assimilate. Practical men often get indignant with those who do not understand. I saw an Englishman on the Continent who was towering mad with a German because the latter spoke a language he could not understand. My innocent questions might have provoked an explosion on the part of the burly officers. So I set my mind to work to unravel the mystery. Fortunately, I was able to borrow from the captain a copy of Bowditch's Navigator, and I pored over this during the intermissions of seasickness. There was certainly one advantage, my dear Richard, in our going to college. We learned that there was such a subject as trigonometry, and solid geometry. I asked myself, How did Columbus find his position at sea? and I found this a very interesting question, and I ventured to ask the captain one night at the dinner table when he seemed to be in a good mood. "My belief," replied the captain, "is that the old chap didn't know where he was most of the time." The captain's ancestors fought the Armada, and a certain prejudice against the Spaniards had been handed down to this generation.

I found that Washington, when he was under twenty, accompanied his sick brother to Bermuda, and during the comparatively long voyage in a sailing vessel was interested in the problems connected with the determination of the position of the ship. These problems were like those he had encountered in land surveying. He had, so to speak, steered his way through a wilderness by means of a compass; he was then being steered over the ocean by the same instrument. I got Philip interested also in navigation and we discussed the problems of sailing together many nights as we walked the deck and saw the masts of the steamer rock about the same stars, never seeming to advance. It was an easy matter to appeal to the boy's interest in Washington, and to stimulate his curiosity in regard to the study of the stars by Columbus. The difficulty of further progress lay in the conception of one's position on the round globe of the earth in place of the customary idea of position on a flat surface.

I recalled to Philip our work in surveying, and showed him how Washington probably gained his first conception of the captain's method of determining his position off the coast of North and South Carolina. I endeavoured to describe to the boy what an immense feeling of satisfaction Bowditch, the distinguished American writer on navigation, must have felt after a return from a long voyage during which he had enriched his mind with study. The men and boys who had been with him had smoked their pipes or gazed idly for hours over the taffrail, while he had studied mathematics and navigation. They had gone into oblivion while he had benefited mankind. Here was the same quality which Washington had displayed. The little observation every day had made great men in time.

I had been fortunate in obtaining some compass cards in Liverpool, one of which I inclose. Among seamen the man who can box a compass, as it is termed, is thought a great man. You will perceive that there are courses laid off on this compass card on which the compass rests.

For instance, there is a course north, then north by east, then north-northeast, and so on. The sailor who can run off the names of these courses glibly out of his head is looked up to as a competent fellow. You will notice also that there are numbers, 1, 2, 3, 4, etc., opposite these courses; these are called points. For instance, one of the points, 4, represents a course of 45° northeast. In the compass box there are fixed points which rep-

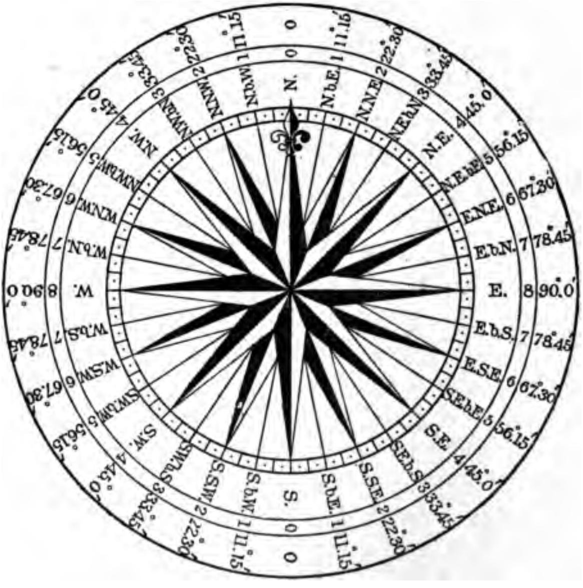

FIG. 11.

resent the north and south points of the compass. When the ship is sailing exactly north the division of the compass card printed N. would rest at this point. The course would then be due north. If the ship changes its course to due west eight points, the W. point of the card would rest against this fixed point; or if it changed its course two points N. N. W., the line N. N. W. would point to the fixed point.

If, for instance, Washington's ship, starting from the latitude 49° 57′ N. sailed S.W. by W. 488 miles,* he could have found her new position by constructing a compass card, or taking a circle divided suitably into degrees and extending the line of five points, which is the course S. W. by W., then laying off on this line the distance 488 miles—letting one inch represent, we will say, 61 miles, so that the distance of 488 miles would be represented by eight inches. If, then, a north and south or meridian line is drawn through the centre of the card, and the point *A* (Fig. 8) connected to *C*, he would have found *AC* to be his new difference of longitude in miles—that is, 405.8 miles—and *BC* his change in latitude, 271.1 miles. Since there are 60 nautical miles to a degree of latitude, by dividing 271.1 by 60 Washington could have found that the new latitude was the old latitude 49° 57′ N. lessened by 4° 31′, or 45° 26′ N.

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* Bowditch's Navigator, 1832, p. 53.

In the same way he could have reduced his departure from the meridian of his starting point to degrees. If he had had a map he could have laid off the distances on the parallels of latitude and longitude and obtained a pictorial view of his position.

Philip puzzled this out with me, and then wanted to know how the captain was sure that he had sailed a distance of 488 miles.

"By the log, of course," said I. Philip had seen the operation of throwing the log to determine the run of the ship, and knew that it was simply a float attached to a rope which was divided into suitable lengths called knots. The number of knots run off a reel in a given time—say ten minutes—would give the miles the ship was making an hour.

"Suppose the ship went so slowly that the log would not run out," said he; "and also that the ship drifted. Moreover, the earth is round, and you have made your calculations on a plane surface." There is certainly one advantage in teaching my dear Philip: you encounter criticism at every step. I was troubled by Philip's question, and took time to consider. It dawned upon me finally that this might be one of the reasons why more accurate methods in navigation were found desirable. Certainly, unless the ship could make the log work, it would not register correctly.

While I was cogitating over Bowditch's Navigator one night in the smoking room of the steamer, surrounded by a heterogeneous crowd of passengers, some playing cards, others reading, and others miserably dozing, I overheard a thrilling account of a late tragedy at sea, in which the captain had been killed and the mate was found to be incompetent to navigate the vessel. The only person of any education on board was a college graduate.

"Of course, he couldn't sail the vessel," remarked one of the passengers, who had often referred to himself as a practical man. I believe he had been buying silks for a New York firm. "College is a place to study athletics, Latin, and Greek. Of course, he couldn't have the slightest knowledge of how to sail a vessel."

I saw the hopeful son of this gentleman sitting in a corner of the smoking room playing poker, and I remarked that he agreed with his father in his denunciation of the usual college curriculum. He sat with his hat on the back of his head, and showed unusual animation only when money-making was the subject of conversation. I did not wish Philip to hear these slurs upon a college education, and I remarked:

"There was a course in navigation and

astronomy when I was in college, and although I do not remember much of the subject, I feel sure I could do something toward navigating a ship. This young college graduate of whom you speak, if he had profited by his college course, should also have known how to get his latitude and longitude roughly."

Further conversation resulted upon this point, and I think it was apparent to Philip that the men who had never been to college had not the advantage possessed even by an idle college man of at least knowing that the science of astronomy and the art of navigation are intimately connected.

It seems that the young college graduate, in truth, was helpless. He was practically in command of the vessel, and he could not use the dead captain's instruments or tables.

"How he must have regretted his waste of opportunities!" I whispered to Philip as we listened to the story of the sea tragedy, while the steamer quivered as the screw came out of the water and the wind roared in the ventilators as we slid down the great slopes of the waves in the darkness of the night.

"What prevented the fellow from steering due west by the compass?" remarked one of the listeners. "He would have brought up off the coast of North Carolina."

"It was a sailing vessel," interposed another, "and the wind might have been west and dead ahead. I don't think that idea would work."

"Well, he could keep tacking," replied the first speaker, and the talk went on and illustrated the state of ignorance of the company.

I fell to imagining myself in the young college graduate's position. What could I do? I found also that Philip had taken the predicament of the collegian to heart, and was resolving in his mind what he could do under similar circumstances. I told him, as we retired to our swaying stateroom, that I would show him on the following day how I would have navigated the ship.

I spent a considerable portion of the night thinking over my ill-digested readings of Bowditch's Navigator, and in trying to recall my college work in astronomy. Although I confess that I paid little attention to my college course in this subject, I had the advantage of the talkers in the smoking room in knowing the general bearing of astronomy upon navigation and of the possibility of applying geometry to the subject. This illustrates, my dear Richard, the advantage of a university education; a college man has a clearer idea of what one can and should know than a man who has had a purely business training from his youth up.

Philip on the following day reminded me of my promise; he had suddenly become interested in the problem of working a ship, and I saw my opportunity of still further keeping up a community of interests. I promised to show him at noon my plan of getting the position of the ship. We had a preliminary talk about the subject of meridians and parallels of latitude. An orange served as a very good model of the globe. The sections of the fruit served as representation of meridians and the circles which I dotted around the orange with my stylographic pen served to represent parallels of latitude. I told Philip that the meridian which passed through Greenwich, near London, was the one from which east and west distances were measured. Since we were sailing west we were increasing our longitude daily, and we were endeavouring to keep pace, so to speak, with the sun.

"You set your watch in London," said I, "and the ship's clock now indicates noon. What time is it by your watch?"

"It's one o'clock," he replied.

"The difference in time between this place on the ocean and Greenwich is one hour, and one hour is equal to fifteen degrees. Our longitude is therefore 15° west—supposing that your watch is not gaining or losing. A man could therefore find his longitude fairly well by means of his watch."

"How can he find out when it is noon?" asked Philip. "A ship's officer always moves the hands of the clock every day to indicate the time of noon."

"The officers of the ship," I replied, "calculate the longitude from their observations. They have various methods, which one can learn from treatises on navigation. We were going to endeavour to find our latitude and longitude by rough and simple means at first, on the supposition that we were suddenly left in command of a ship, the captain having been killed, the mate incompetent, and with a motley crew of sailors who, on our showing the slightest want of knowledge or authority, might put us overboard. In the first place, if we could find the time of noon at any place, we could roughly determine our longitude, and the difference between the time of your watch and the time of noon is the longitude in hours, and each hour is equal to fifteen degrees. This is the way I propose to ascertain the time of noon." Thus saying, I asked him to observe the shadow of a rod which I had mounted perpendicularly upon a board and to mark its extremity as the sun changed its position. Noon was evidently at the time when the shadow changed its direction from a westerly one to an easterly one. At noon the shadow must be thrown on the meridian line or line of longitude. For several days we made this observation, and were interested to compare our results with the official statement of our longitude which was posted in the gangway.

On a starry night, as we paced the deck, I pointed to the constellation of the Great Bear, or Dipper, and showed Philip how to find the north star. "You well know that the two stars farthest from the handle of the Dipper point toward the polestar, this being the brightest star in the straight line through the Pointers. At the north pole," said I, "that polestar is very nearly overhead. If an arctic explorer ever gets close to the north pole, and if he could see the north star, he could determine that he was nearly there, even if he had no instruments. He could lie on his back, and, having attached a string with a weight to the end of a stick or staff, he could ascertain whether, when he sighted along the stick to the polestar, the plummet coincided in direction with the stick."

I asked Philip if he could think of any other way that Nansen, for instance, could have found that he was at the north pole. This was an interesting conundrum, and he, having seen that I had struggled over the conception of a simple method, put his wits to work, and came to me on the following day with this idea:

"You said," he remarked with an ill-concealed air of elation, "that two stars in the constellation of the Great Bear—or, as I call it, the Dipper—always point to the north star. Well, I looked at the position of the Dipper last night, at nine o'clock, and again at midnight, and I found that it was revolving around the north star. Now, it was higher up in the heavens at one time than another; but at the north pole it ought to go round the north star each star of the Dipper always at the same height above the horizon."

"That is true," said I, really delighted with this conception, which, I confess, was new to me.

"Suppose," remarked Philip, "that it was cloudy when the traveller should get to the north pole, how could he ascertain that he was there?"

I was at that moment suffering from a fit of seasickness, and I could only smile in a helpless manner at the boy, who, seeing that I was not in an argumentative mood, ran away, saying that he would ask the captain. Now, this was precisely what I wished the boy not to do, but he was off before he heard my remonstrance. It was some time before he returned. I meanwhile had cudgelled my brains for an answer to this apparently simple question, and had found no solution.

"Well," said I to Philip, "what did the captain say?"

"I found him in his room on the upper deck," said Philip, "and he gave me a very polite invitation to enter. The first mate was with him. When I asked how Nansen could have found that he was at the north pole in cloudy weather, both officers glared at each other, and the captain brought his fist down on the table so that everything rattled.

"'That's the first sensible question I have been asked this voyage,' he growled.

"'How would you tell, Mr. McDonald?' The mate said it was a sticker—blessed if he knew. The captain said that he believed he would make tracks to the southward as fast as he could. I've stuck the captain and mate of this big ship!" exclaimed Philip, dancing with glee.

"Perhaps the compass might aid him," I said.

"Oh, don't say so, father," exclaimed the boy; "at least, don't tell the captain. Of course, you know more than he does."

"Well," said I, "on the whole, I don't believe the compass would be of any assistance. The north pole for the compass is somewhere in British America, and its reading at the real north pole of the earth would not be very different from that a hundred miles one side or the other;

at least, one would know how to interpret its reading. No, the compass would be of no use in indicating when one should arrive at the pole. One must have clear nights or clear days."

"Suppose it should always be day?" said Philip. The questions which boys ask are sometimes searching. I suppose that he had picked up somewhere the information that at certain periods of the year the sun does not set at the north pole, but circles around the horizon, there being no night during those periods.

"Then," said I, "if the sun circled around the horizon for twenty-four hours, always at the same height, the observer would know that he was at the north pole."

XIV.

In reading an old work on astronomy Philip and I discovered that the distance between the stars constituting the pointers was five degrees of arc. We set out to prove this in the following manner: We took a light flat board, and, having stuck a pin in it at one end, we sighted across the top of this pin to one of the stars, and placed another pin in this line of sight. We then, without moving the board or the position of the eye, sighted to the second star, and placed another pin in this line of sight. Having then drawn lines from the pin across which we sighted to the other pin, we measured the angle between the lines by means of a graduated circle such as is used in mechanical drawing, and we found that this angle was five degrees. I said to Philip that now we had a measure in the sky by means of which we could estimate the height of the north star above the horizon, or obtain, in other words, our latitude. Philip speedily held up a cane at arm's length, and having measured off the apparent distance between the pointers, held up the cane again, also at arm's length, and measured the height of the north star above the horizon. He found that this latter distance was about eight times that of the apparent distance between the stars, and this was the approximate latitude of our position. Philip remarked that this was a carpenter's method of getting the latitude by applying a foot rule to the edifice of the sky. We could also survey the sky much as we did our golf grounds. I am afraid he made himself a *persona non grata* with several romantic young ladies one moonlight night by showing them that their estimates of the size of the moon were all inaccurate, and in forcing them to a prosaic agreement by getting them to measure the diameter of the moon with a foot rule held at arm's length, and in terms of the distance between the pointers.

To Philip this measurement did not diminish the poetry of the moonlight. The young ladies, however, not having had his training, could find no amusement in the pursuit of accurate inquiry.

Our conversation in regard to a possible perplexity of a northern explorer was useful, for it brought out the idea that one could use the sun instead of the polar star in determining the latitude of the observer.

It was necessary in the first place to give Philip a clear idea of what latitude meant. I drew the accompanying figure (Fig. 12) to represent the globe of the earth. *E E′* represented the equator, *N* the north pole. The latitude of a place is its distance north or south of the equator in degrees. For instance, the latitude of the north pole, *N*, is *N E′*, or 90°. If an observer is at *A*, he will see the north star in the direction *A N′*. The line *O A* has then taken the position of the line *O N*. The line *M N′* represents the altitude of the north star, *N*, which is so far distant that *O N* and *A N′* are parallel. If we then let *A N′* take the position *O A*, *A M* will fall upon *O E′*. The angle *M A N′* will be equal to the angle *A O E′*, and this latter angle is the latitude of *A*. Therefore the altitude of the

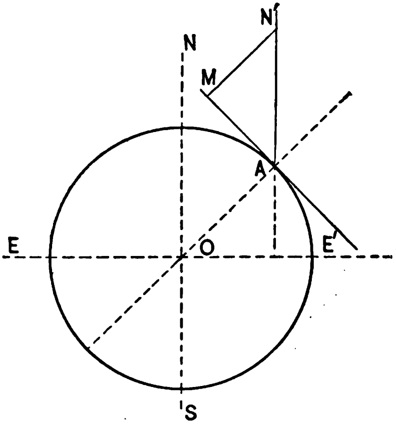

FIG. 12.

polar star above the horizon is equal to the latitude of the place. We amused ourselves at night as we paced the deck in guessing at the altitude of the north star above the sea's horizon. By dividing the distance between a point directly overhead and the sea line into thirds, we could make a fair guess at the height of the polar star. One night we estimated that it was about halfway between the point vertically overhead and the horizon; this made the latitude 45°—that is, one half of 90°, or a quadrant of the earth. The latitude which was posted next day was 43° 20′.

I have referred to the real simplicity of many geometrical propositions, and I wish to extend this remark and to include even the elements of trigonometry in it. Young ladies manifest great ingenuity in working elaborate designs in embroidery; why should they be so much dismayed by diagrams which represent certain relations of lines and their inclinations to each other? Is it not because learning was confined to a few during the middle ages, and they made an unnecessary mystery of it, and so the schoolmen have continued to the present time, jealous of their methods, and insistent upon one's looking through their spectacles and no other? I believe that every boy or girl could be taught geometry and trigonometry, if we took the pains to study how

Nature looks to them, and in what way they can best conceive of the relative size and position of objects. This method, you will remember, is that of Herbert Spencer's father in his little treatise on inventional geometry.

I took the opportunity one evening, in the saloon of the steamer, to put my theory in practice. While we were at a loss for amusement I had stated the above theory to a young Oxford student, who was on his way to America to study, as he informed me, the habits of the natives, and he doubted whether I could give the young ladies who were present the slightest idea of how the latitude was obtained on board ship. Well, I explained that the altitude of the north star above the horizon was equal to the latitude of the observer, and I made one of the young ladies draw a circle and represent a plane surface at a given point, as is represented in Fig. 12. She was made to see that the distance $A\ E'$ represented the observer's distance above the equator or his latitude, but she had some difficulty in seeing that the angular altitude of the north star above the observer's horizon was equal to the angular distance ($A\ E'$). I made her draw the lines $A\ N'$ and $N'\ M$, and then asked her to prove that the angle $M\ A\ N'$, the angular height of the north star, was equal to the latitude $A\ O\ E'$.

She looked at her scissors, for she was engaged in embroidery. "A woman's unfailing resource for cutting a knot," whispered cynically the Oxford student.

She then proceeded to cut out the angle $M\,A\,N'$, and having done this she slipped it over the angle $A\,O\,E'$.

"There," said she. "They are equal, for they fit in every part."

I clapped my hands with the glee of a man who finds his theories vindicated.

"Oh! she is an unusually bright girl—uncommon," remarked my young Englishman, whose obtuseness had occasionally been pierced by a sharper weapon than the scissors. I must say it didn't seem to hurt him, for he often returned to the attack. That, however, is psychology, and we will keep to the vindication of my educational theory.

"Let us see how you will come on in explaining how the sun is used instead of the north star," exclaimed the Oxford man, with an evident malicious desire to corner the American girl. "The use of the polestar is simple enough, but you will notice that the captain always takes the altitude of the sun and not of the polestar. I doubt if you can explain why the altitude of the sun can give him his latitude."

It had been foggy for several days, and there had been much conversation over the failure of the captain to take an observation. I found a certain general interest, therefore, in the subject, for we were approaching a dangerous coast.

"The sun can take the place of the north star," said I, "for its position in the heavens at noon has been calculated by astronomers for every day in the year. This position is always measured from the equator. For instance, to-day at noon the sun is above the equator," and I drew this figure (Fig. 13), in which *A B* represented the latitude of the steamer at *B*, *D E* the angular distance of the sun above the equator, or what is called by astronomers its declination. "The arc *C E* also measures the latitude of the steamer; since this latitude is measured by the angle *B O A*, we can find from a table in a nautical almanac *D E*, we have only to measure *C D* to obtain *C E*, or the latitude—that is, the angle *C O E* or *B O A*. What the captain or other

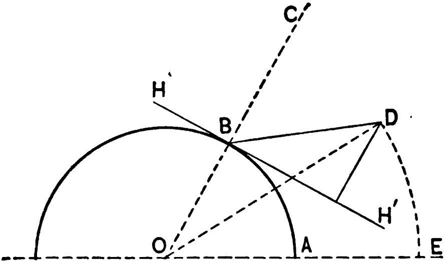

FIG. 13.

officer does, therefore, is to measure the angular distance of the sun, *D*, above the plane of the horizon, *H H′*, with his sextant. If he then subtracts this angle from the right angle *C B H′*, he obtains the angle *C B D*, which he adds to the angle represented by *D E*, and he has the latitude."

I repeated this explanation several times, until I found that the bright young woman comprehended it. Philip, however, had a cloudy brow, and he remarked that the *C B D* was not equal to the angle *C O D*. He did not see how they could both be measured by *C D*. I was delighted by this exhibition of acumen on his part, and I showed him that the distance to the sun, *D*, is so great (90,000,000 miles) that *O* and *B* may be considered as coinciding, being only removed from each other by a distance equal to the radius of the earth (4,000 miles) and that the angle measured at *B* does not differ appreciably from the angle measured from *O*. The skillful navigator, however, makes a suitable correction for this difference.

Then I showed the company a copy of the Nautical Almanac, in which the distances *D E* of the sun from the equator is given for every day in the year.

I was then asked to explain the sextant, by means of which the captain takes the altitude of the sun; but I said that I should lose their attention if I entered into a description of this. It was merely a practical instrument for getting the angular height of the sun above the sea horizon, with delicate adjustments which enabled one to get this height accurately. I called attention to my astrolabe, and I showed how it could be used instead of the sextant to get the approximate height of the sun.

The Oxford student, finding that the American ladies present really followed my explanation, ceased to talk down to them and began to be interesting, and said that undoubtedly Columbus used the astrolabe on his voyage of discovery.

While we were discussing the instrument one of the passengers, coming in from the deck, said that the fog had cleared and that the stars were out. We were all overjoyed and we hastened on deck. The bright young lady wanted to get our latitude by measuring the altitude of the north star, and I assisted her to do it with the astrolabe, for now the instrument was called. She was evidently of a romantic disposition, for she wanted to feel like Columbus as he gazed at the stars for a similar measurement, and she remarked with an awe-struck look upon her pretty countenance: "Just think of those stars up there; they have gazed at Cleopatra, Julius Cæsar, Columbus, and now they gaze at us."

I found this romantic temperament of essential use to Philip in seizing upon my method of getting the latitude and longitude, for he fixed it in his mind by teaching the young lady on the following day how to get the altitude of the sun.

The captain of the steamer saw our attempts to get the latitude of the ship, and treated us at first with a lofty scorn, but I could see him watching Philip out of the corner of his eye, as the latter swayed to and fro directing the sight of a simple astrolabe such as we had used at Zermatt at the sun and steadying the swaying of the plumb line which was connected with it. Finally, the captain's curiosity overcame his fine air of superiority, and meeting us one evening while we were measuring the height of the north star, he invited us into his stateroom at the foot of the bridge. We accepted his invitation, and as we stepped over the threshold we heard the sailor who was pacing the bridge over our head cry out, "All is well," and the response came from another station on the vessel, "All is well."

The captain motioned us to seats, and, having placed himself in his easy-chair at his desk, all resplendent in his brass buttons, inquired into the character of Philip's observations. I saw quickly that, having always been accustomed to a set method of observing with a sextant, he found it difficult to comprehend our simple instrument. When he did he was somewhat critical and referred to corrections for declination and for refraction of the air. "I had a professor from your college on board during my last voyage," he growled, "who had his own sextant and chronometer, and he used to work out the position of the ship. He read his sextant to the minutest point of accuracy, and he was all the morning calculating his results. Well, I told him I'd bean to sea twenty-five year, and I knew when to throw overboard the minutes of the instrument. Why, once when we were fifty miles off Boston light I saw the dome of the Statehouse. There was a mirage, and what use to me was it reading the height of the sun to minutes when my horizon was in such a tipsy state? No, no! a man must use his head as well as his instrument, and I'm glad, sir, to see you inculcating this in your boy. That's the sort of head work that's going to put him forrad. It's what they call gumption. Now do you know, sir, I'm going to state a proposition which I hold to be as good as any mathematical one that Euclid or them other fellows ever enunciated, and it is this:

"You've got to run this steamship, after all, by faith. You've got to have faith in your engineer, and he has got to have faith in his firemen, and they have got to have faith in the men that built this vessel or they wouldn't stay below. And the men that built this steamship have got to have faith way down to the last thing that enters into the ship. I tell you it's faith after all and not instruments that runs the ship.

"I'm a reelegious man," said the captain, with a shout that made the mate peer into the room from the outer darkness. "How is she holding her head?" asked the captain suddenly, changing his tone. The mate said the wind was shifting, and then the captain still further enlarged upon his thesis. While he spoke, the great vessel plunged into the vast hollows of the waves in the darkness. The wind roared into the ventilators, and the boatswain's whistle was heard above the noise of the wind. Philip asked, when the electric light over the captain's head suddenly blinked, if the electricity on board did not interfere with the pointing of the compass.

"That's a sensible question, my lad," ejaculated the officer. "I like your questions and I feel personally obleeged to you for giving Mr. Macdonald, the first mate, that nut to crack about finding the north pole in a fog. He's been revolving that and ruminating it and philosophizing it, and I haven't heard a word about his neuralgia for two days. Well, you ask if the dynamos don't affect the compass. Now, that reminds me of an event which happened on our last voyage. I had been up for two nights during the thickest fog I had ever seen in this latitude. Well, during one night I heard the whistle of another steamer, and we kept our whistle going and sounded signals—no end. I had come into this room for a moment to consult my charts, and as I sat in this very chair the thought came to me: Are not these two ships attracting each other in the fog? Is it not possible that the electrical engine, the dynamos, are so working that the ships are like two great magnets and are steadily being drawn together with a mysterious power? I listened eagerly to the whistles of the approaching steamer which were blown in response to our own. They sounded nearer and nearer. Then the horrible thought occurred to me, 'The two dynamos are drawing the ships together!' I sent for the mate, but no mate came. I changed the course of the steamer, but the whistle sounded still close on to us. Then I saw that the dynamos had altered the compass, and that no reliance could be put upon it. I thought of the five hundred souls I had under my care, and I grew absolutely frantic. Now the whistles of the coming steamer sounded as if they came from our own pipes. Then there came a tremendous whistle, as if the veil of the fog was rent in twain and the glare of the steamer's light was seen, and a shriek went up as if from five hundred women. Do you know what that sound means to a captain's heart? It means death! I braced myself for the shock. It was awesome, and then I heard the cabin boy say, 'It's pretty bad, sir!' as he looked at the breakfast he had brought me spilled over the floor, for he had bolted into the room pursued by a big wave.

"'It might have been much worse,' said I, uncommonly mild to the young gentleman, for I saw that I had been asleep, and I heard the whistles of the steamer far off in the distance as it bore away on another tack. It was all a dream, sir."

XV.

You have asked, my dear Richard, for a detailed account of my building operations in as far as Philip worked with me, and I therefore have no excuses to offer for the somewhat prolix accounts which are to follow. Since you are about to build a house, you may have an interest in our experiments; for I find that general reading leaves little impress on the mind unless a species of laboratory application of it immediately follows.

I was induced to build by various motives; among the most impelling were the following: The old colonial house was tumbling about our heads. The mechanical appliances for comfortable living were entirely wanting, and could not be well adapted to the old house. There was not enough light in the house. Finally, the operation of building promised to add a new interest to life and to be a means of education both to Philip and myself.

I shall not dwell upon the architecture of our new house. It is said that people have been seen to stop and hold up their hands to heaven. I congratulate myself, however, that we can see to read in every room, that our water pipes do not freeze, and that our roof is not continually leaking. I hear that my architect says that he is anxious for one more commission from me—that is, to build my sarcophagus.

Nothing could illustrate the difference in Stifton's manner of viewing practical education and my own more forcibly perhaps than our two methods of building our country houses. We began at the same time to consider the plans. I studied my plans carefully with Philip, and together we examined every detail. Mr. Stifton gave the whole matter into the hands of an architect, asking me what money was for if it was not for getting your work done. He made a calculation of what my time was worth, and pointed out that I could make money by employing service. I preferred to lose a little money in the hope of gaining a valuable opportunity of studying interesting problems with Philip.

In the first place we surveyed the proposed location and studied the slopes of the ground by drawing the contour lines, and then we considered how the house should face in order that the important rooms should receive the most light. We then began to consider the mechanical details of the house. One of the interesting problems was the question of the water supply.

In leading the water into the house we considered the subject of temperature. In our climate all water pipes should be led into the centre of the cellar, or at least should not be placed upon the walls; and we drew a plan of the cellar, showing where all the water pipes of the house should enter or leave. The discussion of the water problem compelled us to study some of the properties of that important medium. Philip had often been annoyed by the slow running of the water in his bath room, and he looked forward to an important improvement in this respect. I knew very little about the laws of the flow of water myself. We accordingly looked up the subject together.

The schoolmaster said that he gave some lectures on fluids, and performed certain experiments which illustrated the weight and pressure of water. Philip, of course, attended the lectures, and doubtless got some valuable information. He said that if he had the schoolmaster's apparatus he could repeat the experiments for my benefit. I replied that the properties of water were so evident that he ought to be able to illustrate them to me with the simplest means.

"Suppose," said I, "we ask the gardener, who seems to have a practical acquaintance with the behaviour of water, how he explains the fact that when one suddenly shuts off the water from a running faucet one can burst a pipe? Philip felt that it would be a little undignified for a man preparing for college to consult the gardener on such a simple point. I was interested, however, in seeing how an uneducated man looked at this phenomenon.

The gardener leaned reflectively on his hoe, and said that he got the first notion of the height of water, and what he called its back lash, when, while a small boy, he dropped a pail of water down the back staircase, and stove the bottom out of the pail and got drenched by the splash. This occurrence set him to thinking; and a little later he was in a railroad accident. In going down grade some of the cars had got detached, and when the engine and baggage car suddenly stopped the detached cars plunged into the baggage car—water likewise was hard to move and hard to stop.

Philip said that these facts didn't explain why the pipe burst, and he said. "Why doesn't stopping of water at the faucet simply thrust upward the water in the pipe? There wasn't any side pressure in the railroad accident."

"Something hez got to give," remarked the gardener. "It is easier to bust the pipe than to lift the weight of water. We know that water presses on all sides of a pipe equally. I've got four faucets in the barn all on the end of a pipe, and I can draw the same amount from all four when they are running at once. If you fill a bladder with water it is round, just as if you filled it with air. The bladder wouldn't be round if the water did not press equally in all directions."

"I think," said I afterward to Philip, "we preserved our dignity sufficiently before James. It is incumbent on you to give him a due sense by some striking experiment of the superiority of your book knowledge to his merely practical information."

"I will get him yet on the subject of electricity," said Philip hopefully.

I confess that I had never attained a clear notion of how the weight of the atmosphere affects the flow of water, and I discussed the matter with Philip. I think the subject arose one day while I was filling a stylographic pen with ink by means of a little glass tube with a rubber bag on one end. You well know that when a little of the air in the bag and glass tube is expelled the ink will rise in the tube to take its place. I asked, "What makes the ink rise?"

"Of course," said Philip, "it's the difference of pressure between the air that is left in the bag and the pressure of the atmosphere outside."

I pressed all the air out of the bag, and it was immediately filled with ink, and then when I lifted the tube out of the receptacle of ink no ink ran out of the stylographic ink-filler.

"What holds it in, then?" said I with a curious air.

"Why, there is no pressure of air in the bag," said Philip, with the laugh of conscious knowledge. "I wish, father, you would take my place at school and let me go gunning to-day."

This levity was perhaps pardonable. I carefully concealed the fact that I was out gunning for Philip.

"If I should connect this ink-filler with a long piece of rubber tube," said I, "can you tell me how far water or ink would rise in the tube if I should lift the filler?"

Philip didn't happen to know; it was, doubtless, explained in the book; in fact, he had something about this in his note-book. Thereupon I told him the story of the judge who, on being continually informed by a lawyer that he had certain papers bearing on the case in his bag, which he had left at home, said, "Wouldn't it be well, Mr. ——, the next time the court sits, to send your bag and remain at home yourself?"

"Let us try the experiment," said I. "We've got a long length of small rubber tubing, and we will attach a somewhat larger bag which we have on a sprinkler."

"How will you know whether water rises into the bag or not?" asked Philip. "You can't see into it."

"It seems to me," I replied, "that if water can not flow into the bag after we have squeezed all the air out, the bag will, as the gardener says, be 'squashed flat' by the pressure of the air."

Well, we tried the experiment, and we got up to a vertical height of about thirty-three feet before the bag remained perfectly flat.

Philip then suddenly remembered a fact, which had not before impressed him, that the weight of a column of water thirty-three feet high could just balance the weight of the atmosphere; for its pressure is fifteen pounds on the square inch.

While we were taking down our rubber tubing outside the window of the barn where we were experimenting, I accidentally slipped off the rubber bag and dropped the tubing to the ground. The water ran out over the walk, and continued to run, lowering the level in the tub in which the other end of the tubing was immersed.

"That's strange," said I. "How is that, James?"

James the gardener said that what water

wouldn't do was not written in any book. Do your best, it was sure to get the upper hand some day.

"Why," remarked Philip, "you took the pressure out of the bag when you squeezed all the air out, and the weight of the atmosphere is forcing the water out of the pipe."

"It won't do it," said I, "if I lift one end of the pipe above the tub."

"The water in the tube will then run back into the tub," replied Philip, "for you have the same pressure of the air on both ends of the tube."

"Oh, I see," said I. "When I suck out the air from the rubber tube and lower its end below the level of the water in the tub, I have the same pressure of the air on the water in the tub and on the end of the tube outside the tub, but there is a little column of water which gives an additional pressure on one side, and there is a want of balance, and the water is forced out by this difference of weight."

"It's real interesting to me to hear you reason, father," said Philip, somewhat ironically yet affectionately. I told him that his processes of reasoning had always possessed great interest for me also.

What our plumber meant by head of water was evidently nothing but the weight of a column of water which exceeded at the house the pressure of the atmosphere. We should have, therefore, to put our water tank, which was filled by a hydraulic ram from our brook, sufficiently high, in order to get a flow in our highest rooms.

Since we saw that the flow of water through a pipe depends upon the difference of level of water in the cistern and that of the point where the water flows out, we perceived that in order to obtain a strong flow we must either have a tank at the top of the house or a cistern on an elevated point above the house, on a knoll to the east of our proposed house. We found by the following simple experiment that if we placed this outside cistern one hundred feet above the level of the cellar of our house we could play a stream of water on the roof of the house, the highest point of which will be sixty feet above the ground. If you pour water into a rubber tube bent into a U-shape, the water will rise to the same level in both branches of the U. Therefore you will doubtless think that the cistern need not be placed any higher than the roof of the house. We found, however, by placing a tub of water in the loft of the stable and leading a rubber pipe from it to the ground, that when the water flowed in the rubber pipe we could not, by directing the stream vertically upward, reach the level of the tub. This was a practical consideration which was forced upon Philip's attention. He had maintained, from reading a page in his text-book, that water would under all conditions rise to the level of the source. It was evident from our experiments that the size of the pipe and the character of the jets we used modified the theoretical statement. A friction arises in the pipes and peculiar and complicated reflex waves occur at the orifice, so that when water flows through narrow pipes it can not reach the level of the source. You will perceive that my object in these experiments was to give a practical turn to the boy's mind, or, in other words, give him the faculty of making estimates.

XVI.

When we considered the question of the roof of the house we found ourselves at sword's point with the architect. He had arranged what he called architectural motives, which certainly would give the house a very picturesque look. Philip, in considering the question, expressed his opinion that we should be living under a sieve in a rainstorm. It seems that the roof of the schoolhouse in the town has many valleys and dormer windows, and these valleys and elevations and depressions in the roof are continually leaking, being exposed to the great changes of temperature of our climate. The boy, I found, had been talking with a sensible Yankee carpenter who had been employed on the schoolhouse.

We concluded that it would be better to have a simple roof, without valleys, and to put whatever art we could muster under waterproof cover. The first question, evidently, having decided upon a simple inclined roof, was to determine what the slope of the sides of the roof should be, in order that the snow and ice should not lodge on it, but should slide off. We tried some experiments on the friction of ice and snow on wood and slate and sheet copper. These experiments were made in the following manner: A board containing a certain weight of the ice or snow was tipped until the ice or snow just began to slide down the board; the angle of inclination of the board to a level surface we called the angle of repose of the snow or ice. We also lined the board with slate in one instance and with sheet copper in another case, and we discovered in this way that the roof need not be so steep if it were covered with slate or copper as if it were shingled with wood. In making these experiments we were struck by the fact that the weight of the sliding mass was the important factor, and that the extent of surface on which the body slid was of little consequence. A brick, for instance, began to slide on our inclined board at the same inclination of the board, whether it rested on its broader side or on its narrower one.

It was evident to us, in thinking the matter over, that a metal covering for the roof would in the course of years prove the most satisfactory. In severe storms water will work under slates even, and this will happen especially on the divisions of the roof when one slope meets another. A metal covering can be made absolutely tight and can be easily repaired. Philip suggested that it might be dangerous in the case of a thunderstorm. Since he could not put such a supposition to the test of experiment, we concluded to ask the professor. He told us that if we connected this metal covering with the ground at the corners of the building, in such a way as to insure a connection with wet earth, we should have the best possible protection from lightning, and he should advise all our neighbours to seek shelter with us in the case of the approach of a severe storm.

Having settled in our mind the question of the roof, we next took up the subject of windows. In treating this question we had another struggle with our architect, who brought to bear on us apparently cogent reasons why the windows should not exceed a certain height and why they should be placed in a certain symmetrical manner. Instead of placing ourselves outside our proposed house and looking at it from such a point of view, Philip and I imagined ourselves inside the house, and asked ourselves many questions in regard to the requisite light for the different rooms.

When one looks into any subject which relates to our daily living one is astonished how much there is to learn. Our ancestors lived in dimly lighted rooms and wore pebbles for spectacles, and bestowed very little thought upon the size and position of their windows, and we copy the loopholes of our ancestors for a sentiment and grow astigmatic, and need a progressive range of spectacles.

I found that Philip desired a room with a north light and a high window, for a drawing-room and a photographic room, and we inquired into the question of the position of the windows in the other rooms of the house.

The higher the windows, of course, the more light one gets into a room. A large amount of light is necessary in order to be able to read in the centre of the room. Philip at first was very desirous that each window in the living rooms should be provided with window seats. I had, however, a sort of superstitious notion that one was apt to catch cold sitting near a window, and Philip tried to prove the unreasonableness of this notion.

I attributed the notion to a traditional belief in draughts of air near a window. Philip said that our scientific house was to have perfectly fitting modern windows, and, having carefully plugged the window seam in one of our rooms with cotton, he asked me to prove the existence of a draught of air near the window. It occurred to me that if he should study the air currents in the room by means of smoke we might learn something.

I accordingly generated some smoke by means of a cigar, and we both watched the movement of air currents in the room. It was soon evident that the smoke rose with the warm air. The currents of air ascending to the ceiling spread out along this until they reached the walls of the room. Then, cooled by the walls and the windows, the cold currents descended near the windows, and the operation was repeated.

I pointed out to Philip that a person sitting near a window in winter is therefore bathed in a descending current of cold air, even if the window is perfectly tight. He admitted that for old gentlemen this was a serious discovery, and I pointed out that since some day he was probably destined to be an old gentleman, and that I should bequeath the house to him, it would be advisable to take the matter into early consideration. We accordingly presented the architect with a plan of high and broad windows, that upset all his ideas of the framing of the house and of its exterior aspect, and he plainly showed that he considered us wanting in the very rudiments of æsthetics. However, light is a blessed thing. Have you never experienced the sedative sensation, after coming out of a room dimly lighted through diamond-shaped window panes, of a glance at the wide spreading sky? Since we could not possess one of the old masters, we resolved to have a plate-glass window eight feet wide by four feet high in our dining room, and we thus had a view of woodland and lawn—a green landscape in summer and a beautiful snow scene in winter—instead of an old master. You see we were not purely utilitarian. Substitutes for such old masters are within the reach of many householders.

A drawing-room with a high and broad north window, I believe, should be provided in every house where there are children and prospective photographers. The children while drawing—and every child, I believe, should draw—need not strain their eyes in such a room, and in it the pleasures of photography are greatly enhanced.

I have often spoken of Philip's attempts at photography in these letters. At first I was tempted to regard his interest in the subject as a species of butterfly fad, soon to flit away; but since he was apparently so much interested I overcame my feeling of inertia and took up the fad with him. He photographed me and I photographed him, and we both shrank back affrighted at our counterfeit presentments. The professor smiled grimly and advised us to put the pictures away and after ten years take them out. "You will become reconciled to them as you grow older," he remarked.

I saw very plainly that we should need a room with a high window; and until we could have such a room we constructed white screens to reflect the light upon the dark side of our countenances, and these attempts taught us much in regard to the distribution of light in a room by means of suitable wall painting or paper. Light-coloured walls and ceilings undoubtedly will flood a room with light more effectually than if they are dark. Do not think that I prefer the whitewashed interiors of the churches in Holland to the richly coloured interiors of the Italian cathedrals. I need bits of colour here and there, and may possibly decide upon an oak-wainscoted room for my dining room.

XVII.

When we came to consider the chimneys of the house, we found it necessary to study the movements of heated air. The ordinary lamp chimney soon came to represent to us a fireplace. In it there was a draught of air through the base of the chimney, caused by the rising of the heated air. In our proposed open fireplaces, however, we did not wish so much heat to be carried off at the top of the chimney. We wished to have it radiated out into the room, unaccompanied by smoke. I discovered, in looking up the subject of fireplaces, that Count Rumford was considered an authority on the proper method of building them; and I soon got as much interested in the count as in the fireplaces. Knowing Philip's great interest in events of the Revolution, I excited the revolutionary fire in him before I turned his attention to our homeside fires. We rode on bicycles to the birthplace of Benjamin Thompson. —Count Rumford—a distance of about ten miles from my estate, and found a well-preserved old-fashioned house. In a lower room on the ground floor—a room so low that a very tall man would have been obliged to stoop—we were informed the count was born a humble American lad, who was destined to be the companion and adviser of princes, and who made a discovery that marked an epoch in the history of science.

I told Philip of the early troubles of the count—that he was suspected of being a Tory, and how he was secreted in the barn of his friend Loammi Baldwin, the celebrated engineer. We were informed that the house of the latter was also still standing, and mounting our bicycles we set out in search of it. Not far from the birthplace of Count Rumford we came upon an old colonial mansion in a valley, shaded in front by very tall trees, which almost cut off the view of the quaint front. On the lawn was the following placard: "The home of Loammi Baldwin, who discovered the Baldwin apple."

We endeavoured to picture to ourselves the hurried hiding of the fugitive by his friend the distinguished engineer—possibly the crouching of the future great man behind a barrel of apples, listening, while the cattle chewed their cuds, to the angry questions of an excited band of patriotic farmers who were endeavouring to ascertain his whereabouts from Loammi Baldwin. Philip wondered if the count thought out a design for a fireplace that chilly night. I replied that I supposed his mind was full of dreams of future accomplishment. Doubtless his chill of the night was remembered in future years, when his mind ran upon the great problems of heat. It is well in youth to store up materials to be worked over in mature years. Philip was in a more or less ironical mood, and wondered if it would be well for him to spend a night in a cellar in order to gain material to be worked over subsequently. I told him that if his mind had been turned to philosophical thought, great suggestions might come to him even in a cellar. On returning from our excursion I found, in a memoir of the count, the following letter to Loammi Baldwin:

"I know you must be extremely altered, or a philosophical and mathematical correspondence would be very agreeable to you. I have therefore taken the liberty to propose the following problem, which I send you, not so much for the difficulty as the oddness of the solution:

"A certain cistern has three brass cocks, one of which will empty it in fifteen minutes, one in thirty minutes, and the other in sixty minutes. Question: How long would it take to empty the cistern if all three of the cocks were to be opened at once? If you are fond of a correspondence of this kind, and will favour me with an easy question, arithmetical or algebraical, I will endeavour to give as good an account of it as possible. If you find out an answer to the above immediately, I hope you will not take it as an affront, my proposing anything which you may think so easy, for I must confess I scarcely ever met with any little notion that puzzled me so much in my life."

I suggested to Philip that the future count may have whiled away the hours in the cellar in considering this problem. It is said that, after escaping from the retreat offered him by his friend, he joined the British forces in Boston in the winter of 1775. That winter saw two great men in close proximity: George Washington in Cambridge, destined to become the father of his country, and Benjamin Thompson in Boston, the founder of the mechanical theory of heat—a theory which has revolutionized our views of the world about us. At that time Washington was entirely out of powder, and Benjamin Thompson was a man without a country, with a mind which ran on the effects of powder and the best method of using it. It was doubtless due to his habit of close observation of natural phenomena and to his natural tact and good manners that he attracted the attention of General Gates and the British officers, for he was selected to bear despatches to England announcing the evacuation of Boston.

I suggested to Philip to make a little historical investigation in regard to the occupation of Benjamin Franklin at that time, another close observer of natural phenomena. My object was to find, if possible, a point in history from which a suddenly awakened interest might spread, just as my taste for mechanics had been aroused by the study of a practical question.

In a library Philip found a pamphlet entitled "An Account of the newly invented Pennsylvania Fireplace. Printed and sold by B. Franklin, 1744"; and, with the eagerness of a youthful critic to pull down an exemplar, pointed out to me that Rumford had been anticipated by Franklin in regard to the proper method of building a fireplace, for the Franklin stove embodied the physical ideas of the Rumford fireplace. We studied the matter together, and I pointed out that Franklin's stove was of iron, while Rumford's fireplaces were intended to be of brick or earthenware. The latter, moreover, laid especial stress on framing the sides of the fireplace so that much heat should be radiated into the room and less should be lost in passing up the chimney. Franklin's structure was entirely of iron. It was remarkable, however, in embodying the later idea of a hot-air furnace with its cold-air flue. The ideas of Franklin were fully as philosophical as those of Rumford, and their reflections upon the economy of fuel are almost identical. We came to the conclusion that economy leaned to Franklin's side.

In the course of his historical investigation Philip came across this amusing mathematical problem proposed by Benjamin Franklin to his friend Joseph Priestley, the distinguished English philosopher. Philip found an interesting parallel between the two proposers of problems and the receivers. This was Benjamin Franklin's problem, proposed after the battle of Bunker Hill in 1775: "Britain, at the expense of three millions, has killed one hundred and fifty Yankees this campaign, which is twenty thousand pounds a head; at Bunker's Hill she gained a mile of ground, half of which she lost again by our taking post on Ploughed Hill. During the same time sixty thousand children have been born in America. From these data his mathematical head will easily calculate the time and expense necessary to kill us all and conquer our whole territory."

The result of Philip's inquiry showed that Franklin had just returned from England, having ended his labours there to enlighten the government and prevent war, while Benjamin

Thompson was about to set out for the same country to begin his remarkable career. The latter was not thirty, while Franklin was more than twice as old. While Thompson was with the British in Boston, Franklin was visiting Washington in Cambridge and conferring with him in regard to raising troops for the defence of the country. It struck us as a remarkable coincidence that the two great men who were destined to advance science to such a degree, and to lay the foundation for the great applications of electricity which we see around us, should have been so near each other, and yet not in communication.

Our trip to the birthplace of Count Rumford and our subsequent study of his remarkable career led us to be interested in his method of building a fireplace, and Philip instructed the builder of our house in the count's method, which consisted in placing the sides of the fireplace at an obtuse angle with the back of it instead of running these sides in perpendicular to this back, and in discarding all iron or other metallic surfaces in the fireplaces, for substances such as metals absorb heat to a great degree and do not allow such a favourable distribution of it as fire brick. Count Rumford, moreover, has given particular directions in regard to the size and position of the throat of the fireplace; it must be comparatively small, and should be placed directly over the fire.

The consideration of Count Rumford's plan of building fireplaces led us to study the effect of draught on fires. The ordinary kerosene-lamp chimney, I have said, showed us the importance of a fresh supply of air at the base of the flame. In the course of our experiments one day a vessel filled with oil took fire. Philip was about to pour a pail of water upon it, but I held his arm and quickly covered the burning receptacle with the empty pail and with an old piece of carpeting. The effect was so immediate in smothering the flame that I confess I was surprised.

There is evidently much to be learned both in making fires and in putting them out. Count Rumford devoted great attention to the subject of the proper method of building wood fires as well as to the proper fireplaces. Philip made an abstract for me of the count's researches on this subject, and came to the conclusion that the proper way to build an open wood fire is to provide a large back log and also a comparatively large front log; to support the back log on a bed of ashes, and the front log on andirons a short distance from the back log; then to build the fire in the space between, by means of a few judiciously disposed pieces of kindling and small wood arranged crisscross with a large log on top. Such a fire we found to have good lasting qualities and to dispel gloom.

You remember Sydney Smith's prescription against the blues: "Have regard to the effects of tea and coffee, and keep open fires." Certainly many of the ideals of Philip shaped themselves doubtless as he sat with me in the winter evenings talking over some intellectual subject and gazing at the flickering fire. He learned from Professor Scribain a method of adding to the interest of the open fire by making a driftwood effect. The method is extremely simple. A piece of copper or brass tubing, perforated with small holes on one side, is sparsely filled with some crystals of sal ammoniac, which can be obtained for a few cents at any electrical supply store or wholesale druggist. This tube is placed in the embers of the fire, between the back log and the fore log, and when it is sufficiently heated beautiful flashes of blue and crimson light appear among the embers, giving all the effect of a piece of burning driftwood. The sal ammoniac, I found, was used to fill the electrical batteries which we employed for exciting our doorbell.

My neighbour Stifton, while Philip and I were looking into the operation of the natural laws which were to serve us, had employed experts who worked as his servants. He paid for their services, and was thus saved the trouble of acquainting himself with mere details. I am quoting him. "Make science your servant," he remarked to me as he showed me over his fine mansion which had all the modern improvements. While he took evident pride in not knowing anything about the mechanical details, he showed me in his chamber at the head of his bed a series of electrical push buttons. "When I push this one," said he, "I turn on the water in the bathroom. When the bath is full, yonder bell sounds. I can test the temperature of the bath by touching another button. Science, you see, is made my servant. While my bath is filling I lie in bed and read Burke's speeches. 'The proper study of mankind is man'—hey? I do not stand over my cook and examine his processes. I hire him to cook, and I hire natural forces in the same way."

I suggested that a time might come when a knowledge of processes might be of great assistance.

"You can always get such things done for you, my dear sir. Philip and you are wasting your time." We had had so many discussions on this point that I forbore to open it again.

A week after this conversation Stifton attended until a late hour a heated discussion over a political matter. He returned to his home in an extremely nervous condition and went to bed. Unfortunately, the electrical switches were out of order, and he could not put out the lights in the bedchamber. They stared at the tired man in a relentless manner, and the thought of passing a sleepless night grew to be intolerable. The lights could not be covered up. They would not out. They would be seen. The servants had become the masters and ruled at last. While the poor victim tossed and tumbled and hid his head beneath the bedclothes until he gasped for air and was forced to gaze at his masters. The house was full of guests, and there was no possibility of changing the sleeping room. The only resource was to descend to the reception rooms and make up a bed on a lounge. This Stifton was compelled to do, and he passed a very uncomfortable night. Philip happened to call in the morning and learned of the difficulty. He showed our neighbour that all that was necessary to do was to unscrew the lamps from the sockets, and thus break the electrical connections. I have no doubt that some day he will flood his bathroom while he is reading Burke's speeches.

XVIII.

I HAVE become much interested in the mechanical details of a house, and I have obtained many useful hints by visiting scientific laboratories. A modern house is in one sense a laboratory. Usually, however, it is a very antiquated one; and it seems to me that every householder should make himself acquainted with modern methods of scientific living. I found, on visiting Professor Scribain's laboratory, a very simple contrivance for heating a small amount of water, which I immediately adopted and have placed in my pantry. It is called the Bunsen burner. I have an indistinct remembrance that we used to see it on the lecture-room table when we were in college, but since in those days we got our physics from a text-book and did not use apparatus, the burner made no impression, certainly upon me.

The burner consists simply of a piece of brass tubing supplied at one end with gas through a narrow orifice. If you should light the gas it of course burns with a yellow flame like that of any ordinary gas flame. If, however, one provides small openings in the tubing at the point where the gas enters, and then takes care to light the gas at the top of the cylinder, a draught of air is created through the holes in the side of the cylinder or chimney. This air mingles with the gas and produces a very hot blue flame. It is a species of blast lamp, and one can heat a teakettle over such a burner in a very short time. Such a burner saves the necessity of building a large fire in a range in order to obtain a cup of tea or to fill a hot-water bottle at midnight. I have had a simple nozzle put on the gas fixture in the pantry and have connected the burner to it by means of a short piece of rubber tubing.

By means of this burner Philip and I settled many points in regard to the behaviour of steam and heated water which were not clear in our minds. Naturally, in building a house the question arises, How should it be heated?—and I was surprised to find that every system of heating had its fierce advocates and its fierce enemies; and I set out to discover with Philip some of the underlying scientific principles of heating by steam, by hot water, and by hot air.

I found that we did not clearly understand the action of steam, and on consultation with Philip we studied the action of an ordinary teakettle in the following manner:

Taking about ten feet of the long rubber tube which we used to study the pressure of a column of water, we filled it with water, holding the two ends in a horizontal position. We then slipped one end over the nozzle of the teakettle, and having lighted the Bunsen burner under the teakettle, we waited to see what would happen. We were not long in doubt, for when the water began to boil in the kettle the expanding steam forced the water out of the end of the rubber tube.

It occurred then to both of us to lift one end of the tube, after it had been filled with water, higher than the nozzle of the kettle, so that the weight of the column of rising water in the tube should balance the pressure of steam at the nozzle. This was an interesting experiment, for we had something similar to a geyser. The column of water rose and fell in the tube, some water issuing from the upper end of the tube. As we lifted the end of the tube higher, steam lifted the lid of the kettle and issued from it, and then we could lower the end of the tube without causing a flow of water from it.

I pointed out to Philip that since a column of water thirty-three feet high exerts a pressure of fifteen pounds at its base, we could find what was the pressure of steam in the teakettle by raising the end of the tube until the head of water just caused steam to issue from the lid of the kettle. I suggested to Philip that we should see what would happen if, while steam was flowing through the rubber pipe, we should coil a portion of it and immerse it in cold water. He laughed at my ignorance, and said that the steam would condense in the rubber tube. I wanted an ocular proof, and therefore coiled up a portion of the tube and put it in a pail of cold water. The flow of steam from the end of the tube immediately ceased for a moment, and then some distilled water or condensed water was ejected from the pipe, and again there was a pause. I suggested to Philip that he might get very pure water in this way for his photographic work, and I asked him to design for me a larger apparatus for obtaining a large quantity of such desirable water for the uses of the house. Any one who has suffered from the use of hard water would highly appreciate the softness of such distilled water.

The large apparatus consisted merely of a larger kettle and of a coil of glass, which was immersed in a vessel of water through which cold water flowed.

Philip began to be somewhat surprised by my ignorance, and saw the necessity of teaching me. My want of knowledge was "too crass."

We found that when we immersed the rubber tube through which the steam was flowing in the bucket of cold water, the flow of steam continued with little interruption. Philip looked dumfounded, for he had expected that so much steam would condense in the rubber tube that there would be a flow of water instead of steam. I suggested that we should make a little coil of lead pipe, and substitute it for the coil of rubber tubing in the water. We found that we could readily obtain lead pipe about the size of a lead pencil, with a bore of one third of an inch, and we accordingly carried out this idea. The flow of steam immediately ceased when we immersed the coil in the cold water, and a stream of distilled water began to flow from the open end of the piece of rubber tubing which was connected with the lead coil. The rubber tubing, being a poor conductor of heat, had kept in the heat of the steam, and prevented its condensation, but the lead, being an excellent conductor, had taken the heat from the steam, and the fall of temperature had led to condensation.

This experiment illustrated in a forcible way the advantage of the practical method of study of the laws of Nature over the book method. Philip had not remonstrated against my using the coil of rubber tubing, although he had read that metals are better conductors for heat than such substances as rubber. He had not obtained by reading a feeling sense, so to speak, of the magnitude of the quantities involved, that the lead coil would, roughly speaking, yield twenty times as much condensed water as the rubber coil.

To confess the truth, I had him where I wanted him, for I was very well content to be the pupil. I couldn't understand his description of the circulation of steam in the method of steam heating, and he said he would make a model for me. I found that my kettle experiment had suggested to him the possibility of experimenting with simple means, for he went to a hardware store and got a plumber to make his model. It consisted merely of a vessel somewhat like a coffee pot. A rubber tube was slipped upon the nozzle and was connected with a little coil of lead tubing about the size of a lead pencil; the other end of the lead coil was connected by another piece of tubing with an additional nozzle soldered into the coffee pot on the opposite side of the first nozzle and below it. When the pot was filled with water to the level of the upper nozzle, as it was heated, water circulated through the little coil passing from the upper nozzle to the lower, into the pot which constituted the boiler. The lid of the pot was held down by a weight; this lid represented a safety valve. I complimented Philip on the simplicity of his model, and said that I too would get a model made for hot-water heating.

"The only difference between steam heating and hot-water heating is this," said Philip. "Hot water circulates instead of steam."

"How is it made to circulate?" I asked.

"You've got to show," said Philip with a laugh, which led me to infer that he thought he had set me a difficult problem.

I took up the challenge and got a plumber to make the following apparatus: Two tin cans were provided, with nozzles at their sides near their bottoms. I connected these nozzles by a piece of rubber tubing, filled the cans with water, and taking another piece of rubber tubbing I filled it with water, and closing the two ends with the fingers I immersed them, one in one vessel and one in the other. I then put the Bunsen burner under the right-hand vessel and sprinkled some fine sawdust in the water of this vessel. In a short while we saw that the particles had been carried by the ascending currents of heated water through the upper rubber tube into the adjoining vessel of cold water. Heat was apparently carried by the circulating currents of water. All that it is necessary to do to heat by hot water is to provide a boiler with two pipes, one ascending, and the other descending and returning to the boiler, the boiler and the pipes being completely filled with water. The rubber tubes and the supplementary vessel which is not directly heated by the burner represent the hot-water heaters in such a system.

Philip agreed that I had fulfilled my agreement; but not to be outdone, he pointed out that I might have taken him into the kitchen and shown him the system in constant operation in connection with the kitchen range.

"We get our hot water for our morning baths," he remarked in a very professional manner, "by having just such an arrangement which you show in your model. The water back, so called, of the range, corresponds to the vessel of water which you heat and which in the case of the range is heated by the fire in the latter. The pipe filled with water ascends to the bathroom and descends again to the large vessel filled with water, which again is connected with the water back."

"A little reflection would have saved the trouble of making the model," I replied. "By the way, what causes the thumping noise we sometimes hear in the pipes and vessels connected with the water back?"

"Why, my dear father, haven't you ever seen steam issuing from the hot-water faucet, and haven't you noticed that the thumping noise disappears when the steam is blown off?"

I said that the mysterious action of the kitchen apparatus was now completely understood, and we proposed in our new bathrooms to place a coil of pipe through which the hot water should circulate and should heat the room as well as provide hot water for the baths.

The behaviour of the lead coil of pipe in quickly conducting away the heat of steam set us both to thinking about the conduction of heat. Philip noticed at breakfast the unusual brightness of the hot-water urn, and he wondered whether it held heat better when it was brightly polished. I suggested that we should try an experiment to test this point. Evidently, if the brightness of the surface tended to a loss of heat it would be better to have a coffee pot with a dull surface. To test the question we took two vessels of the same size and the same material, two silver mugs, one was brightly polished and the other was blackened in the soot of a lamp. We filled the mugs with the same quantity of hot water and put a thermometer in each of the mugs. The thermometer in the blackened mug showed that this mug radiated the heat faster than the polished mug. In order to make sure of this fact we polished the blackened mug and blackened the one that had been preserved bright—that is, we interchanged the mugs and the conditions of the experiment in order to make sure that the effect observed was not due to some accidental condition, and we again found that the blackened mug radiated the heat much faster than the polished mug. It was therefore plainly evident that it is desirable to have a high polish on our coffee and tea pots. We then looked up the subject in a text-book on heat, and found that a lampblacked surface radiated more heat than a brightly polished silver surface.

When we considered the problem of lighting the house we were in much perplexity. The builder and the architect wished to know whether gaspipes should be laid throughout the building or conduits for electric wires, and some of our friends spoke of mysterious accidents which had resulted from electric wires. This was a subject with which we could not experiment. We accordingly applied to Professor Scribain for information. He invited us to an evening lecture on electric lighting, and I send you Philip's report of the lecture:

"The most modern method of lighting a house is by electricity, and I shall first call your attention to this method. Let us take the lighting of this lecture room as an example of the simplest case of electric lighting, and we will leave out of consideration for the present the method of producing the electrical current, and we will confine our attention to the distribution of the current to the lamps.

"The current comes into this room through one large wire and returns through a similar wire to the source of the supply. The wires can be thought of as the rails of a railroad, while the sleepers of the railroad can represent the disposition of the lamps—that is, the lamps bridge the distance between the tracks. We can run our wires, which can be thought of as railroads, anywhere about the ceiling of this room, through the flooring, around corners, just as we can run railroads over mountains and through valleys. In one case we distribute light and power, in the other case, that of the railroad, we distribute supplies and people. The sleepers or ties in the case of the railroad are, however, inert masses—sleepers—while the analogous electrical arrangement gives forth light and heat.

"Let us see how the light and heat are produced. If you examine one of these little glass globes from which the light emanates, you will see that the globe contains a filament of carbon. The electric current flowing through this filament raises it to a white heat. If this filament were in air, the oxygen of the air would speedily cause it to break and volatilize, and the light would consequently disappear. Accordingly, the filament is inclosed in a glass bulb from which the air is exhausted. There is said to be a vacuum in these globes. This statement, however, is not scientifically accurate. The amount of residual air in these globes, however, is small, and the time of burning up the filament in the lamp is greatly deferred. It is often said that electric lighting produces no heat. It certainly produces far less heat than gas. If you will touch one of these incandescent lamps, you will perceive that the globe is decidedly hot. By removing the air the conduction of the heat from the glowing carbon filament is lessened. In popular language there is nothing in the globe to conduct the heat to the air of the room. Now, each of these little glow lamps uses only a portion of the electricity which comes into the room through the large conducting wires or rails, as we have pictured them. How shall we prevent too much current from entering these lamps? For too great a current would raise them to a dazzling white heat, and then the carbon filament would volatilize and break.

"The simplest safeguard is called a fuse. This fuse is a piece of wire made of an alloy which melts as soon as the electric current flowing through it rises above a certain strength. Let me interpose a bit of this wire between this source of electricity and this lamp. You perceive that it safely carries the current to the lamp and the lamp burns at a safe temperature. I will now greatly increase the current flowing to the lamp through the fuse. You perceive that the fuse burns up, or, in common language, is blown out, and the lamp is protected from being blown out. The electric cars also have similar fuses to prevent too strong a current flowing through the motors which are propelling the car. You doubtless have been in a car when a fuse is blown out.

"On a recent trial of horseless carriages in France the fuse on a storage-battery carriage was blown out and the carriage came to a standstill. One of the passengers had a piece of chocolate which was covered with tinfoil. A piece of this tinfoil was put in the place of the blown-out fuse, and the horseless carriage proceeded safely to its destination. A very little knowledge of electricity thus saved the passengers the necessity of taking a twenty-mile walk.

"In arranging the wires, therefore, for lighting a house we must provide large enough conductors to bring in the current which will be sufficient for providing enough electricity to supply the requisite number of lamps. We must also provide fuses in order that by no possibility shall the amount of electricity exceed a safe limit. These fuses are placed in porcelain boxes in order to protect the woodwork of the house from the heat produced when the fuse is melted and volatilized. Here is such a fuse box. It is extremely simple in construction. The current enters at *A* and goes out at *B*. Between *A* and *B* is a bit of wire made of a fusible alloy.

"The commonest method at present of wiring a house is to bring the main conductors of electricity—the rails, so to speak—into the house through hollow iron pipes, like the ordinary gas pipes. Instead of gas in the pipes we then have a bundle of insulated copper wires. If the wires were not insulated—that is, wrapped with cotton or rubber or other nonconducting material—they would instantly become heated; electric lights would be formed in the gas tube, and the house might speedily be set on fire. In this resides the chief danger of electric lighting—namely, the formation of what is called an electric arc between the wires of such an iron conduit or pipe.

"Suppose we bring two wires carrying a current of electricity from and to a suitable source near together. When the wires are wrapped with cotton or other insulating material you would perceive no action between them—there is no heating effect. If we remove or abrade the coverings, the metallic wires can then touch each other, and you would perceive, as I shall show you later, an intense evolution of heat. This might happen inside a pipe, inside a ceiling, unless the wires are properly insulated inside the iron pipe. Now, the fuses on the wires are so arranged that they will burn out if the wires should happen to touch in the inside of the iron pipes or conduits. This is an additional safeguard; and if the process of wiring is done by competent electricians the danger from fire by electric lighting I believe is less than that from the ordinary gas lighting. In electric lighting there is absolutely no danger from explosion. There are two safeguards against fire—namely, the insulation of the wires and the fuse. The metallic tubing prevents danger of the abrading of the coatings of the wire, from the settling of the walls of the house or from rats. It may be asked, Will the fuse wire always burn or be blown out if a dangerous current should be established on the electric wires? It is true that fuses are not always reliable; but a large limit of safety can be employed. The fuse is only a rough safeguard; frequently it does not blow out when it should, and it does blow out when it should not. The main dependence in house electric lighting is on the insulation of the wires. The wires should be well covered, and the inside of the pipes through which they are drawn should be lined with porcelain or similar material. It is evident that every precaution should be taken against any possibility of chemical action inside the pipes which contain the wires; for this chemical action might disintegrate the covering of the wires, and thus allow the metal of the separate wires to touch.

"There is a method of wiring which is perfectly safe, and you can see an example of it in this lecture room. The wires carrying the currents are entirely on the surface of the walls of the room, in channels under wood mouldings. There is a large distance between the wires, and they can be examined at any time without the necessity of taking up floorings. Many public buildings are now wired in this manner, the mouldings being more or less concealed from observation on the walls. Personally, I should prefer to have my house wired in this manner.

"The housekeeper, having been reasonably satisfied in regard to the safety of the present method of lighting a house by electricity, will undoubtedly ask, What is the cost of this method? and is there an accurate method of measuring the amount of electricity which is supplied to the house? The cost of electric lighting is undoubtedly more than lighting by gas; how much more it is difficult to answer. The electric metre and the gas metre may be called boon companions. They are certainly not instruments of precision. I believe that the electric metre measures the amount of electricity used as accurately as the ordinary gas metre measures the amount of gas consumed. In the gas metre the pressure of the gas is made to work a simple wheel-like arrangement, and the turns of the wheel registered on dials like that of a watch indicate the amount of gas that has passed through the apparatus. In the case of electricity the electrical current is made to register its strength either by a chemical decomposition which it effects, or by the revolution of a little motor. The electricity registers itself; and both the gas and the electricity have the most honest intentions, but the apparatus is sometimes creaky.

"To illustrate how a to-and-fro or alternating current of electricity can turn a series of wheels and thus register itself, I have arranged this apparatus. Here is a hollow ball which is suspended above the end of this coil of wire through which a to-and-fro current of electricity is passing of sufficient strength to supply this electric light. When I bring this plate of copper under the balls you will perceive that the ball rotates, and the speed with which it rotates is a measure of the strength of the current which supplies the lamp. On this principle a metre could be constructed which, by means of dials, could register the amount of electricity that is supplied to the house. There are many forms of such metres, and they depend upon the rotations excited by the electric current. If the house is lighted by a steady current, such as in the Edison system, the electricity is measured not by rotations produced by the current, but by the amount of zinc or other metal which is deposited by the effect of the current; this amount is proportional to the strength of the current, and can be weighed at suitable intervals. In many cities the to-and-fro current, or the alternating current, is used for lighting houses, while the steady current is employed for the arc light on the streets and for running the electric cars. The advantage of the to-and-fro current is its great range. This range is attained by means of what is called a transformer, which is placed either on the outside of the house or in the cellar. This transformer in principle consists merely of two coils, which are entirely separate. Here is a model of one. The electric current pulsates through this coil *A*, and a current is produced in the neighbouring coil. This current may be less in intensity than the current in the exciting coil or it may be greater. This is accomplished by having less or more turns of wire in the secondary coil.

"You will perceive that I can light a little lamp connected with the secondary coil even when there is a plate of glass between the two coils. This could not be done if a steady current should flow in the exciting coil.

"When there are many houses on the electric circuit the to-and-fro current enables one to obtain a great range of transformation.

"Suppose, then, that your house is properly wired; the grouping and position of the lamps is entirely a matter of taste and of convenience. You are supplied with lamps of a certain candle power. The lamps in this lecture room are said to be fifteen-candle power—that is, each lamp will give as much light as fifteen standard candles of a definite weight and a definite material. In order to answer the question of the cost of electric lighting compared with that of gas, we must be sure that we are getting electric lamps of a certain candle power, for the amount of illumination we are paying for is measured by the candle power. In this point resides the great uncertainty in regard to the cost of electric lighting; for the electric lights may burn up to candle power when they are first installed in your house, and after some months they may have fallen from fifteen-candle power to ten or twelve, and you may be paying for more light than you receive. This deterioration of the lamps is always going on, and the householder should specify that his lamps should be renewed at definite intervals—that is, after so many hundred hours of burning.

"Unfortunately, there is no simple apparatus by means of which the householder can determine whether his lamps are up to candle power. The simplest photometer is that invented by Count Rumford. It consists merely of a vertical rod, and the two shadows thrown by two sources of light on a screen are made equal by placing the two lights at greater or less distances from the screen. For instance, let me compare the light of this little electric light with that of this candle. Here on the screen are the two shadows thrown, one by the electric light and the other by the candle, and I shall endeavour to make these shadows seem of the same intensity. It can be proved that the intensities of the two sources of light are proportional to the square of their distances from the screen.

"In this manner one could decide whether his lights are diminishing in brightness or not.

"In the base of each of the modern incandescent lamps is a button which enables one to turn the current on the lamp or shut it off. In some of the modern forms one can turn the light down as one can with gas or kerosene lights. This can be accomplished by putting a resistance or obstacle to the electric current in the base of the lamp. Such a resistance can be made out of plumbago and a substance like ground plaster, and the button enables one to include a greater or less length or amount of this resistance in the electric circuit, and thus increase or diminish the current which flows to the lamp.

"The steadiness of the electric light is one of its greatest merits, and one can generally obtain this steadiness, although we have all of us seen mysterious alterations in our electric lights, due to some trouble at the central station, where the light is produced. During last summer I was in a hotel where the lights blinked in a most painful manner. I entered into a scientific explanation of the probable cause of this blinking with the proprietor of the hotel, attributing it to imperfect brushes on the electrical machines. The proprietor listened with an urbane smile and said, "Professor, I have a drunken engineer."

"Now, one of the advantages in living in a large town or city is the ability to light one's house by this most luxurious of all systems of lighting—the system of electric lighting. If one lives in the country at a distance from a great hotel, or from a town where there is a lighting station, one can not enjoy the luxury of electric lighting unless one puts in a private plant.

These are generally too expensive. One can use water power, if it is available, to generate electricity, but it is generally found too expensive unless it is used on a very large scale. One can also use windmills to store up electricity in storage cells, but this is probably the most expensive method that can be employed. A small steam engine or a gas engine is the most practical form of generator of electricity for a country house. It is thought by some people that the rise and fall of the tides might be utilized for seaside residences. The cost, however, of suitable reservoirs would be very great; and a great ironclad war ship rising and falling with the daily tides would barely develop twenty horse power.

"I have called your attention thus far entirely to electric lighting. There is a new method of lighting by incandescence—which at present is extending—in which the incandescence is produced not by electricity but by gas. The gas jet employed by this method is produced by what is known as the Bunsen burner. When a bit of platinum wire is held in the flame of this burner it becomes luminous, or incandescent. Instead of platinum a mantle made of certain oxides of the metals zirconium and lanthanum is placed in the flame, and this mantle becomes highly luminous. This new light is very economical compared with the ordinary gaslight or the electric light. The mantle, however, deteriorates, and should be frequently renewed.

"In many houses and in most hotels the lights are placed too high for comfort in reading. Last summer I did not find a single hotel in England, France, or Switzerland in which one could read with comfort, for the electric lights were feeble and were placed far above one's head. The disposition of lights should be regulated by the character of the wall paper or by the hangings in the room. In a library where the walls are covered with books the lights should be lower than in a reception room. There is a growing demand for more light in modern houses, for we are outgrowing the old-fashioned notion that it is not well to read in too strong a light, and so one reads in too feeble a light. It is sometimes feared that the electric light injures the eyesight. There is, you well know, a distinction in electric lights. There is the incandescent lamp which is used in lighting houses, and the arc lamp which is used on the streets and in certain factories. It has never been shown that the light from the incandescent electric lamp differs in any respect from that from gas or kerosene. Its use is probably less injurious to the eyes than that of the latter, for it does not heat the eyes to the same extent. The arc electric light, such as is used on the streets, is, however, injurious to the eyes and to the skin, if one is subjected long to its powerful rays. Fortunately, we can not use these arc lights in lighting a house.

"We have seen that the chief danger to a house from electric lighting is from defective insulation. Is it possible that lightning discharges might enter a house through the electric wires and set it afire? This might happen in the following way: Here are two insulated wires near each other which are connected to a source of electricity, such as a transformer. The insulation effectually prevents a voltaic arc being formed between these wires. If I remove the insulation and touch the metallic wires, you perceive that a voltaic arc is formed and intense heat is generated. Let me now show how a lightning discharge can start such a voltaic arc. Here is an electrical machine which can produce minute lightning discharges. Let me connect it in such a manner that the sparks jump between the insulated wires. You will see that the sparks open a way for the electricity, and a voltaic arc is formed between the insulated wires. The jumping of even a portion of a lightning discharge from one insulated wire to another might therefore cause a fire. This danger is guarded against by lightning protectors, outside the house, which conduct the lightning discharges to the ground.

In a properly wired house the danger from lightning in the direction I have explained can be entirely obviated.

"The following questions are often asked, Is it well in building a new house to have it wired for electrical lighting? Will not new methods speedily supersede those at present in use? Will not electricity be generated in an entirely different manner from that employed at present? Shall we not, for instance, be able to obtain electricity by burning coal in our furnaces? Should we not wait, for we have seen great changes in electrical apparatus during the past few years? In reply to these questions I have said, let us be luxurious and comfortable in the present. The present system is entirely practical, and can be made as safe as gas lighting. The modern dynamo is a very perfect machine, and admits of but little improvement. The improvement, I believe, will come in the steam engines which drive the dynamo. Wires must always be used in electric lighting, unless indeed we shall be able to flood the entire house with an illumination like that of the sun from some wireless source. At present there is absolutely no economical method of obtaining electricity directly from coal.

"From what I have said, I think it is evident that, of the modern methods of lighting a house, that of electric lighting is the most flexible and comfortable."

Philip and I were in the proper condition for assimilating this lecture, for we were interested in an immediate application of the information it conveyed. We were destined soon to put our suddenly acquired knowledge of electricity to good use. During a recent blizzard we were returning home from the city, and the electrics having come to a standstill on account of the drifting snow, we were forced to make our way on foot. The storm had begun with rain, which turned to sleet and then to snow. The branches of the trees were bent to the ground by their heavy burdens, and the sides of the houses looked as if they were cased with marble. The telegraph wires and the electric-light wires were transformed into great white cables, and in many places had fallen across the street. In one spot we came across an electric lamp, half buried in a snowdrift. It seemed like a monster cat snarling and spitting as the wind shrieked and howled around it. Occasionally the wires leading to it would cross, and then flashes like lightning would gleam in the storm and convert the driving snow into wraiths gibbering and dancing in the hubbub of the elements. It was a terrible night, and the electric wires added greatly to the danger, for they were extended across the roads half concealed by the snow. We came across two horses that had been killed by stepping on the live wires and had been abandoned by their owners, who had fled to some place of shelter.

We had not struggled far before we came across the carriage of Mr. Stifton. The coachman did not dare to go on, for there was a live wire stretched across the road. Stifton's wife was with him. She is an invalid, and it really looked as if they both would be compelled to spend the night in the carriage. Stifton was returning from a meeting of the Merchants' Club, where he had made a speech against putting electric wires under ground. In the speech he had made ironical references to "perfessers," as he termed them, men who in the seclusion of universities were unaccustomed to dealing with large practical questions, where men and not figments of philosophy were the factors. He invited Philip and myself to spend the night with himself and wife in the carriage. The coachman was also to be included. The poor horses were apparently doomed, for if they advanced they would be killed by the live wires, and if they remained they would freeze to death. Philip took a small shawl which Mrs. Stifton had in her possession, and having wrapped it around one of the live wires pulled the lamp to one side of the road, and then in the same manner caught hold of the mass of tangled wires and removed them from the roadway.

Stifton looked aghast when he saw Philip and myself seize the wires, having protected our hands by means of dry cloth. The way having been cleared, the coachman whipped up his horses and the equipage floundered on, while we struggled on behind, ready with our modicum of knowledge to save the orator, who believed with Pope that "the proper study of mankind is man."

When we came to consider the protection of the house from lightning, we felt that we could not experiment, and so we went to Professor Scribain to obtain his views. We found him experimenting with a prodigiously powerful apparatus for producing electric sparks, which closely resembled lightning discharges, for they were six feet in length and made a terrific snap as they lighted up the dark room with sudden distinctness. You will remember that the sparks we saw when we were in college were not more than a foot long, and they were of small body, compared with those the professor exhibited to us. These were veritable thunderbolts, and their production was made possible by the remarkable advance of this century in the perfection of the dynamo machine.

The behaviour of these great sparks was in every respect similar to that of lightning, and it was perfectly evident that it would be of no use to insulate the lightning rods from the roof of the house by porcelain or glass insulators; for the electric stress is so great in these powerful discharges that such insulation is of little avail. I was especially interested in observing that the discharges often passed over the surface of water in preference to passing through the water. When a wet rope was hung between the terminals of the machine which produced these discharges the sparks followed the surface of the rope. When glass tubes filled with water were interposed in the path of the discharge they were shattered by sparks which followed the surface of the liquid inside the tubes. This experiment explains why trees are shattered by a lightning discharge, which, entering the tree, immediately seeks the outside, and forms a disruptive discharge. We both saw how important it was to have large earth plates on which our lightning conductors should terminate.

The subject of the use of electricity in a modern house is now added to our consideration of heating, ventilation, plumbing, and the other subjects which pertain to our comfort in daily living. We had for some time discarded our old colonial knocker, and had put in a doorbell.

When, however, I found one evening the door knob had been pulled out about a foot and was aimlessly swinging in the wind, I decided to put in electric bells; and I asked Philip to study up the subject, in order to instruct me; for I did not want any appliance in the house with which I was not thoroughly acquainted, conceiving this acquisition of knowledge to be my duty to the household. Philip accordingly went to the professor, who did not refer him to the electrical-supply man, but manifested much interest in our questions.

"You must not expect," said he, "that electricity is going to give you a perfect doorbell. You will not have the same kind of failures as you have experienced, but you will have some interesting ones. I myself have given up electricity, and have returned to a mechanical doorbell, simply because I do not wish to be bothered with batteries and their failures. However, you are young." Thus saying, he took Philip into his laboratory and explained the construction of an electrical battery and the proper arrangement of an electrical circuit, and how the wires should run at a distance from metallic pipes and should be well insulated from each other. Philip entered somewhat fully into the theory of the galvanic cell. I regarded it as a source of electricity which was supplied by keeping it full of a solution of sal ammoniac in water. Philip thoroughly informed himself in regard to its defects. The principal ones were the necessity of renewing the solution and the necessity of preventing the wires which led to the poles of the cell from becoming corroded. This corrosion demands that these wires should be scraped bright from time to time.

It seems that there are at least two sources of trouble with electrical bells in a house. One is with the mechanism of the bell itself, and the other is with the battery. When the doorbell refuses to sound, it is probable that there is not sufficient liquid in the battery, or that the battery connections require scraping and the screws need tightening. Philip had various devices to ascertain whether the battery was in good order. The simplest and most efficacious was what he called a buzzer. This was a tiny arrangement about the size of a bicycle lock. On connecting it by means of wires to the battery, if the latter was in good order, it gave forth a noise like a confined bumblebee. Philip explained the contrivance to me at great length and with evident knowledge. I was content to see him acquiring electrical knowledge in advance of myself, having the immense satisfaction of feeling that I had set off the train.

To me the buzzer still remains a noisy enigma. I know how to use it, however, and every householder who has an electrical doorbell should have one in his house.

In collecting my memoranda in regard to Philip's home education I find frequent references in regard to the importance of persistent effort, day by day. The result of a few minutes devoted every day to drawing and to German or French, at home, was very gratifying when Philip reached the period of fourteen years.

My experiments in natural philosophy, moreover, conducted with him, led to the habit of looking up a subject in a practical way; in such a manner that he could feel his subject by its important bearing on problems of daily living. I may be slow in my mental habits, for I am a commonplace man, but I find that my general reading in history, for instance, made little impression on my mind. When, however, I looked up some particular point—made an investigation, for instance, into the condition of affairs which prevailed in my native town in the time of King George—I spread out from that epoch over the whole period of colonial times, and got a taste for historical investigation. I therefore, as you have seen from these memoranda, started Philip on his historical investigation of the Rumford fireplace and the Franklin stove. He got interested also in American history in general. It seems to me that the method of investigation should be employed more in education, for human interest, when once excited, spreads like a forest fire.

If the student can be made to take the teacher's place and expound to the teacher, great progress can be made. Following out this idea, I required of Philip as he grew older the presentation of somewhat longer pieces of work. For instance, I was interested to ascertain how great speed could be obtained by means of electricity, and I asked Philip to look up the subject, and read a paper to a club of gentlemen who meet occasionally at my house. I send you a copy of his paper, with some paternal pride, for I think the boy acquitted himself fairly well. He got a good deal out of his effort, for he had to sustain himself in a vigorous cross-questioning from the club. I took the opportunity to point out to him certain faults in elocution, and my recommendation made a powerful impression, for the iron, so to speak, was hot.

Philip began his paper with a statement of the highest rate of speed which had been attained on land—something a little over a mile a minute—and then he went on to say:

"This result has been obtained with the reciprocating engine—that is, the engine due to the genius of Watt, in which the piston moves to and fro in a straight line—steam being alternately admitted and driven out or condensed at each end of the stroke. Now, the greatest speed of this reciprocating motion is far below what can be obtained by rotary motion, such as that of a wheel revolving on an axis. All our electric motors have this rotary motion, and are not reciprocating engines: for instance, the electric motors on the street cars consist of two parts—stationary electro-magnets, and a revolving portion called the armature. The surface of this armature can attain a velocity of over 3,000 feet per minute. If the axle of the car constituted also the axis of the armature, this speed would make the car wheels turn with this velocity, or even a greater velocity.

"Gears are therefore employed to produce a lower rate of speed at the wheels. Perhaps the most popular illustration of the effect of gearing is seen in the case of the bicycle. In this machine a comparatively large wheel or gear with teeth is connected with the treadle, and a chain connects this wheel with a small wheel on the axle of the rear wheel. The little wheel, in order to measure the amount of the chain which passes around the large wheel in one revolution of this larger wheel, has to turn on its axis about 2.5 times. One complete turn of the treadle of the bicycle by means of the foot therefore drives the rear wheel around 2.5 times. The length of the circumference of the bicycle wheel is 7.3 feet. One revolution of the bicycle wheel, therefore, drives one over the ground about eighteen feet. A bicyclist has recently ridden a mile in one minute and twenty-five seconds. His feet must have revolved with the treadle nearly five times a second in order to obtain this velocity, or nearly as fast as the reciprocating action of the piston of an express locomotive.

"In the attainment of great speed on a bicycle the most important factor is the resistance of the air. In bicycle races, therefore, the racer is preceded by so-called pacers—that is, riders on tandems or triplets or sextets, who, coming in at set periods, and succeeding each other, take away the extreme resistance of the wind from the racer, who therefore rides in a rarefied space. Professor Boys, of South Kensington, remarks in a late criticism of a book on bicycles and tricycles, by Mr. Sharp:

"'A man who can drive his machine under present conditions through the air at 30 miles an hour could, if road and machine resistances only were to be met, drive his machine at the rate of 330 miles an hour, or if he can actually go 20 miles an hour, could drive 100 miles an hour. This shows the importance of pace-making.

Professor Boyd suggests, perhaps facetiously, that a large box or a small house with glass sides, big enough to entirely surround the rider, but with a safe margin, should be dragged by steam or other power along at gradually increasing speed until the inclosed rider should show that he is beginning to lag. Of course, there would be no floor or bottom to the box. Or a day should be chosen when the barometer is very low, for a fall of one inch in the barometer, if it reduced the air resistance by $\frac{1}{30}$ of an inch, might mean a gain of a second in a minute. The resistance of the air and of water certainly increases at a higher rate than the cube of the velocity.'

"In general, a bicycle rider is not sanguine in regard to the possibility of flying machines, for he realizes the effect of the pressure of the wind. A simple method of estimating this pressure when riding at a known rate of speed is as follows: Erect upon the crossbar of the bicycle two supports, which are connected at the top by a wire. On this wire hang by eyelets a flat piece of cardboard, or thin sheet of metal, like zinc. When the wind blows against this suspended sheet it will make an angle with the vertical supports. This angle can be measured by fixing a graduated paper scale on one of the supports.

"The weight of the sheet, W, acting at its centre, multiplied by $A\,B$, the distance or leverage from the centre or fulcrum B will be balanced by the pressure P of the wind, acting with the leverage $B\,C$. Knowing the angle a and the weight W, we shall have the relation W multiplied by $A\,B = P$ multiplied by $B\,C$, or, if we are not mathematicians, we can construct a diagram, with the aid of the graduated circle, and estimate P, or we can find by a delicate spring balance what force P is necessary to hold the sheet so that it will make an angle with the vertical through $B\,C$.

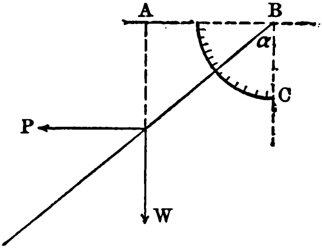

FIG. 14.

"When a person says he is riding a machine with 70 gear he means that, if he were riding one of the old-fashioned lofty bicycles 70 inches in diameter, without any chain, one turn of the treadle would carry him over the same distance as the combination of gears on the two axles of the modern machine—that is, the one wheel 70 inches in diameter will roll out a distance of about 18 feet on the ground in one revolution, and this is about the distance traversed by one revolution of the treadle in the 70-gear two-wheel modern bicycle.

"The axle of the ordinary electric-car motor can easily attain a velocity of about one thousand revolutions in a minute. If, therefore, this axle or revolving axis of the motor constituted also the axle of the car, the wheels of the car would revolve with this velocity. One revolution of the ordinary car wheel moves the car forward about five feet. If, therefore, the axle revolved 1,000 times a minute, the car would move 5,000 feet in a minute. A mile is 5,280 feet, and the car would move nearly a mile a minute. It is necessary, therefore, to use gears to reduce this speed. If we should reverse the gear wheels on the ordinary bicycle and put the small gear wheel, which is usually put on the axis of the rear wheel, on the treadle axis, one turn of the treadle would move the bicycle not through 18 feet, but only through 7 feet. In the case of the electric car this is what is done: A small gear is made to turn a large gear. This large gear or cog wheel has about three times as many teeth as the little gear or pinion on the axle of the motor, and thus the speed of 5,000 feet a minute is reduced to 1,666 feet a minute, or, we will say, to three tenths of a mile per minute, or 18 miles an hour.

"I have devoted considerable time to this question of reducing or increasing speed by means of wheels of different sizes, for this is an important point in modern methods of obtaining great speed. It is evident from our previous discussion that the ordinary electric car could run without gearing down a mile a minute; and one can readily run an electric motor 3,000 revolutions a minute instead of 1,000 a minute, which is about the rate a common form of motor on the ordinary electric car attains. Now, 3,000 revolutions a minute would force the car over 15,000 feet a minute, or nearly three miles a minute, or 180 miles an hour. It is said that this speed can be maintained by electrical motors; and it is only a practical question of a good road bed and the proper electrical contacts between the motors and the rails which prevents the attainment and maintenance of this rate of speed.

"The third-rail system is an interesting substitute for the trolley. You are aware that the current which propels the car enters the motor through the ordinary rails of the road and leaves by a third rail which is placed midway on the track between the two outer rails. This forms a very substantial system, and a car could be driven with great velocity over it. We perceive that electricity can convert the comparatively slow-moving reciprocating action of a steam engine into a far swifter rotary motion. A reciprocating action of four to six a second in the case of the bicycle rider and the express engine is far slower than the rotation of the armature of an electric motor which may reach sixty revolutions a second. We appear to be entering upon a new era of motors for the attainment of great speed. The rotary form seems to be assuming a greater prominence than the reciprocating form, which is the marked characteristic of the mechanism of the Watt steam engine."

Having thus allowed Philip to exhibit himself to you, it is time to conclude this account of his early education.

In one of your letters, my dear Richard, you intimate that my home education is too utilitarian, for you ask, "Who turns Philip's attention to the poets and to literature in general?" I confess that I have largely abandoned the development of this side of his nature to his mother, and I have selected a small library which contains the standard writers, both in prose and verse. We also strive to speak of something intellectual at our repasts, for football and baseball have from time to time threatened to be the only topics at our meals. But to return to your suspicion that scientific training tends to displace poetry, I think that this is a fallacy; for science can not fail to stimulate the imagination. I came across the other day the following interesting passage in Noctes Ambrosianæ. Christopher North is speaking with James Hogg, the Ettrick Shepherd:

"*North:* You thus see with half an eye, James, that poetry and science are identical. Or, rather, that as imagination is the highest kind of intellect, so poetry is the highest kind of science. Thus, James, it is only in an age of science that anything worth the name of poetry can exist. In a rude age there may be bursts of passion—of imagination even—which, if you or any other man whom I esteem insists on calling them poetry, I am willing so to designate. In that case almost all human language is poetry. Nor am I sure that from the province of such inspiration are we justified in excluding the cawing of rooks or the gabbling of geese, and certainly not the more impassioned lyrical effusions of monkeys.

"*Shepherd:* Queer devils, monkeys!

"*North:* Will any antiquary or archæologist show me a bit of poetry as broad as the palm of my hand worth the toss-up of a tinker's farthing—the produce of uncivilized man?"

When the poetic mind has fully grasped the stupendous bearings of the problems of science, then we may have a new school of poetry. I think, however, I am justified in adding a definite thinker on phenomena constantly before us to the army of those who having eyes see not, and having ears do not understand.

My labors in home education terminated when Philip went to college. His mother and I had no fear of his going astray; for we had laid the foundation of his moral structure at home—the only place, in my opinion, where it can be laid. I can claim, moreover, to have given him the investigating habit of mind, without which little real progress can be made in the acquirement of any subject.

Philip, you well know, graduated from the university with credit; and this story of a commonplace man's efforts with a bright son draws to a close.

THE END.

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